CONSEIL PERMANENT INTERNATIONAL POUR
L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT — DANEMARK

RAPPORTS
ET
PROCÈS-VERBAUX DES RÉUNIONS

VOLUME CXXVIII

II

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TO
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PART II

SHELLFISH INVESTIGATIONS

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PREFACE

In 1948 I drew the attention of the International Council to the fact that in my opinion the interest paid to shellfish was not in accordance with their commercial and scientific importance.

Although it may be true that in no one country is any species of shellfish of primary economic importance, the commercial value of shellfish taken as a whole reaches about the same amount as the value of one of our very important fishes, the plaice.

If one compares, however, the attention which has been paid to plaice and to shellfish, either in the meetings or in the publications of the Council, one is struck by the great difference which exists. I suppose this difference is mainly due to the beneficial influence of the activity of the Council, the regular meetings of the Area Committees providing a permanent stimulus for intensifying the research on different kinds of fishes.

In no one area are shellfish of supreme interest to science or industry, and consequently no one of the Area Committees has considered it to be their specific task to take care of shellfish.

Another reason why shellfish experts have no effective means of cooperation may be found in the fact that they are mostly specialists who as a rule do not visit the meetings of the Council.

Consequently the shellfish experts are in a position considerably inferior to that of workers in marine fishery research, who have the benefit of their annual contact. All of them have to work separately without the stimulus of an organized exchange of views and experience with their colleagues in other countries.

The Council agreed that something should be done, and it was decided that a Special Scientific Meeting on Shellfish should be held in 1949, the author being nominated convenor.

The great number of contributions, a list of which may be found in the table of contents, proves that the opportunity offered by the decision of the Council was well used, and that the need was widely felt for a closer cooperation and for discussion of mutual problems.

The author was elected as Chairman of the meeting, Dr. A. Dannevig was nominated reporter on Crustacea and Dr. P. Korringa reporter on Mollusca. As a great number of papers on Mollusca were submitted it was not possible to have them reviewed by each author separately and Dr. Korringa was asked to give a general review of all the papers together. This review has been published in the *Journal du Conseil*, Vol. XVII, 1.

The contributions on both Crustacea and Mollusca give a very clear survey of the state of science at present. We see from them that in the Crustacea especially problems on population and on overfishing and the possibilities of its control are dealt with. Species that are most threatened by overfishing are *Homarus vulgaris* and *Pandalus borealis*. The papers of Dannevig, Havinga, Poulsen, Rasmussen and Thomas deal, *inter alia*, with this problem. In *Crangon vulgaris* the influence of fishing on the density of the population could not be ascertained (Havinga).

In the most important species of Mollusca the problem of overfishing has been definitely overcome by culture methods. While the oyster has proved to be an organism that is extremely sensitive to overfishing, nearly all the natural banks being extinguished by intensive fishing, artificial culture has provided a very efficient method of producing much larger quantities of oysters than has been possible from the natural banks.

A description of the present situation, mainly with regard to oysters, is given in communications by Cole and Knight-Jones (England), Millar (Scotland), Halewijck and Leloup (Belgium), Lambert (France), Spärck (Denmark), Vilela (Portugal).

The culture of oysters starts with young individuals (spat) that grow in their natural state in the open sea, and the only method for increasing their number consists of affording a suitable substratum on which the spat may set. In many cases, however, it is impossible to collect a sufficient number of young individuals in this way. In order to be independent of the natural production of spat, attempts to cultivate spat in tanks are often made. This procedure, however, encounters great difficulties, and a paper by Korringa is dealing with this extremely important problem.

When monocultures, such as those of oysters, are being developed, diseases and pests are likely to find a fertile field in which to flourish. The shell-disease in

the oyster, and *Crepidula fornicata* as an oyster pest, are described by KORRINGA in two papers.

While nearly all the research in Europe on molluscs concentrates on oysters and mussels it is noteworthy that VILELA in his paper on the ecology of *Tapes decussatus* opens a new field of investigation.

Finally, although problems of sanitary control are not yet investigated by universal methods, those in use are described by SHERWOOD in England, by LAMBERT in France and by GRIJNS in the Netherlands.

I have given this brief review of the subjects dealt with in the various contributions to show how in all the countries concerned research is concentrated on closely related problems.

It is quite evident that a closer cooperation between the experts occupied with these problems would greatly benefit research. In many cases extension of our knowledge would not only result in scientific success, but it would also involve direct financial advantage to the industry. In this respect shellfish present much less of a problem than do the real fishes that live in the open sea, for nearly all the commercial species of shellfish have a very restricted distribution, mostly in territorial waters. Thus if further knowledge should reveal the need for measures that would lead to an increase in production, these measures could be put into operation in each country separately without any difficulty.

At the end of the meeting the participants expressed unanimously their opinion that the contact established in the Special Scientific Meeting should have a permanent form. Without such a continuation of contact, shellfish research would fall back to its former unorganized position, much to the detriment of the industry. For the International Council the establishing of such an organization will be a task by which it will greatly indebt the industry.

Only once before in the history of the Council has a meeting of Shellfish experts been promoted. At the meeting of the Council in 1931 it was decided "that a conference on the subject of sanitary control of shellfish should be held, with the view to the final adoption of a standard method of bacteriological survey of edible molluscs, especially of oysters and mussels". This meeting was held in the Netherlands, at Middelburgh, 1932. No practical results were forthcoming, however, mainly due to the fact that this was merely an incidental meeting, no steps being taken to continue the research and to organize the work. It is hoped that this time the Special Scientific Meeting in Edinburgh will initiate the organization and stimulation of shellfish research in the whole domain of the International Council.

B. HAVINGA.

1.

The British Oyster Industry and its Problems.

By

H. A. Cole

Introduction.

The survey of the oyster beds on the coasts of England and Wales made by Bulstrode (1896), although primarily for the purpose of investigating the relation between oysters and disease, gives a good picture of the industry as it was at the close of the last century and forms a satisfactory basis for an examination of the causes of the great decline in the quantity of oysters marketed that occurred in the following fifty years. The problem to-day is, broadly speaking, to reverse this decline and to expand and cheapen production so that oysters may be removed from the luxury market and again become a food of general consumption. To elucidate the nature of this problem, or set of problems, it will be necessary to assess not only the contribution that can be made by scientific research but also, briefly, difficulties experienced in marketing, including the protection of the public from disease transmitted by polluted shellfish.

The Decline in Production.

The statistics of landings of oysters at British Ports (Table 1) do not give an accurate picture of the production from British beds for the following reasons:—

(a) In addition to British native oysters they include a variable proportion of foreign relaid oysters, principally French but, including also Portuguese (*Gryphaea angulata* Lamarck) and, up to 1939, American oysters (*Gryphaea virginica* Gmelin).

(b) Oysters landed at one port and sold for relaying and fattening elsewhere may appear twice in the statistics, on the second occasion when landed and sent to market. Since it is a regular practice to market the bulk of the oysters for relaying from certain beds, e. g., those in the River Crouch and the River Fal, the numbers involved may be substantial, although only those surviving to market size will appear twice in the figures.

(c) The statistics are not complete as they do not include landings from the Percuel River, St. Mawes, Falmouth and certain other beds of less importance. Further the figures for Falmouth do not include the production from the beds at Penryn nor oysters sold for direct consumption from layings in the Upper Fal. The figures for the Helford River appear only in the total landings and are not shown separately.

A detailed examination of these statistics would be out of place here, but it will be realised that while the recording of oysters sold for subsequent relaying tends to inflate the figures of total landings, the deficiencies listed under (c) above are serious, since the Falmouth district during the last few years has become one of the main sources of market oysters.

Reliable figures of production from certain beds are fortunately available in the Annual Returns made under certain Fishery Orders, which granted the sole right of fishing for oysters to certain bodies over defined areas of bottom. For example, since 1876 the Corporation of Truro has exercised control over the oyster fishery in the whole of the Upper Fal and reliable figures for the production from these beds are available (Table 2). Similarly the right of several fishery was granted in 1878 to the Tollesbury and Mersea Native Oyster Fishery Co. Ltd., over the greater part of the estuary of the Blackwater, Essex, and some of the creeks running into it. The fluctuations in the production from this estuary, which includes for the years 1936—1940 a proportion of relaid French oysters, are given in Table 3. These two fisheries have been selected since they present contrasting conditions, the Blackwater being infested with slipper limpets (*Crepidula fornicata* Say) and American whelk tingles (*Urosalpinx cinerea* Say) and being subject to severe frost, while the Fal is free of imported pests (although occasional slipper limpets have been found during the last two years) and hard frost is most unusual.

Tables 2 and 3 show that a most serious decline

in the production from these fisheries set in during 1920 and continued throughout the twenties and early thirties. Some improvement was evident in the late thirties, but in Essex the ground regained was lost during the exceptionally severe winters of 1939/40 and 1946/47, and has not been regained. In Cornwall these winters, although far more severe than those normally experienced, did not cause very substantial losses and were not sufficient to affect seriously the steady recovery of the Fal fishery.

Since 1939 the landings shown in Table 1 do not include American oysters, but the import of Portuguese oysters was continued on a reduced scale during the war years so as to keep the grounds in production. These oysters are laid principally at Brightlingsea and West Mersea and in certain creeks running into the River Roach, all in the County of Essex. Table 4 gives particulars of foreign oysters imported for relaying or breeding.

Principal Problems with a Discussion of Possible Remedies.

The principal causes of the decline in oyster production may be defined as:—repeated failures in spatfall, disease, prevalence of imported pests, industrial and sewage pollution, closure of beds and interruption of cultivation during war-time and exceptionally severe winters.

1. Spatfall Failures.

A thorough investigation of the factors controlling oyster spatfall on British beds is in progress, and sufficient has been done to enable us to reach certain conclusions. The subject is being dealt with in more detail by KNIGHT JONES and only the general conclusions will be stated here. It is clear that there are good and bad spatfall years which cannot be related simply to weather or the quantity of breeding oysters. Water temperature is important but summers which are generally described as "hot" or "cool" are not necessarily more and less favourable for the settlement of oyster spat. In 1946 for example, the summer in Essex and Kent was considered to be one of the poorest for many years yet there was a good settlement, and many instances have been recorded of hot dry summers with little spat. Our work has confirmed KORRINGA's view (1940) that good spatfalls cannot be expected on seriously understocked fisheries, despite the known fecundity of breeding oysters

Table 1.
Quantity and Value of Oysters landed in England and Wales.
(British Landings.)

Year	Oysters (Thousands) No.	£
1918	26,078	131
1919	31,111	201
1920	39,439	255
1921	31,027	208
1922	23,666	177
1923	18,102	152
1924	16,973	147
1925	16,740	151
1926	15,858	160
1927	9,712	101
1928	8,058	87
1929	7,377	60
1930	6,937	58
1931	7,045	62
1932	10,740	89
1933	10,719	96
1934	12,009	107
1935	15,799	140
1936	19,287	176
1937	16,583	142
1938	16,364	133
1939	12,193	101
1940	8,859	74
1941	9,800	94
1942	5,540	75
1943	4,946	67
1944	4,535	65
1945	5,651	108
1946	7,850	135
1947	6,675	110
1948	7,167	128

Table 2.
Oyster Production from the Upper Fal, Cornwall.
(Truro Port Fishery Orders, 1876 and 1936.)

Year	Natives (Thousands)
1918	ca. 11,500
1919	ca. 11,000
1920	ca. 14,000
1921	ca. 16,000
1922	ca. 9,000
1923	ca. 15,000
1924	ca. 8,000
1925	ca. 11,000
1926	ca. 3,500
1927	ca. 1,500
1928	ca. 600
1929	100
1930	750
1931	600
1932	400
1933	375
1934	225
1935	191
1936	103
1937	341
1938	546
1939	312
1940	590
1941	1,115
1942	1,358
1943	1,566
1944	1,637
1945	1,116
1946	1,732
1947	1,519
1948	1,782

Table 3.
Oyster Production from the River Blackwater, Essex.
(Tollesbury and Mersea Fishery Orders, 1878 and 1938.)

Year	Natives (Thousands)	French (Thousands)
1918	10,109	—
1919	2,281	—
1920	7,631	—
1921	3,688	—
1922	1,587	—
1923	901	—
1924	No record	—
1925	1,603	—
1926	1,499	—
1927	1,051	—
1928	661	—
1929	962	—
1930	123	—
1931	695	—
1932	295	—
1933	563	—
1934	335	—
1935	532	—
1936	268	800
1937	111	2,801
1938	922	6,140
1939	562	7,571
1940	—	3,551
1941	68	—
1942	187	—
1943	251	—
1944	167	—
1945	207	—
1946	227	—
1947	136	—
1948	131	—

Table 4. Imports of Oysters for Breeding or Relaying.

Year	Total (Thousands)	Value (Thousand £)	Percentage France	Netherlands	Portugal	U.S.A.
1922..	12,011	33	56·07	43·93	—	—
1923..	8,778	21	99·58	0·42	—	—
1924..	12,149	42	98·28	1·72	—	—
1925..	7,099	4	99·54	0·46	—	—
1926..	9,570	6	61·98	—	38·02	—
1927..	16,795	14	45·70	—	48·14	4·69
1928..	10,098	11	59·21	3·28	29·84	7·67
1929..	7,244	8	79·91	1·24	15·81	3·04
1930..	12,150	10	50·72	13·59	25·81	9·88
1931..	5,826	7	39·11	0·96	41·49	18·44
1932..	9,507	19	55·04	4·84	23·93	16·19
1933..	14,225	31	65·55	0·84	13·74	14·57
1934..	15,970	46	64·58	—	19·15	15·50
1935..	23,662	58	72·06	—	16·14	11·80
1936..	26,177	77	83·81	—	6·77	9·42
1937..	40,899	89	87·04	—	5·22	7·74
1938..	27,949	43	85·29	—	7·56	7·15
1939..	19,954	—	82·79	—	12·69	4·52
1940..	15,740	—	94·56	—	5·44	—
1941..	—	—	—	—	—	—
1942..	4,238	—	—	—	100·00	—
1943..	5,930	—	—	—	100·00	—
1944..	4,532	—	—	—	95·98	—
1945..	5,000	—	—	—	100·00	—
1946..	1,801	—	86·67	—	13·33	—
1947..	18,710	—	73·91	—	26·09	—

(Cole, 1941). A very dense concentration of oyster larvae is required to produce a good crop of spat under the relatively unfavourable conditions existing on the east coast, where large areas of once productive oyster ground are now derelict. The proportion of the larger fisheries, e. g., in the Blackwater and the Crouch, which is adequately cultivated and in a fit condition for the settlement of spat is now very small, the remainder being over-run with slipper limpets and mud and semi-derelict. On the Cornish beds conditions are more favourable and generally speaking the grounds are fairly well-cultivated, here spatfalls of commercial importance are more frequent, e. g., in the Helford River very good spatfalls occurred in both 1940 and 1947 and the intervening years were by no means unproductive.

Cole and Knight Jones (1949) have shown the importance of the gregarious habit in the settlement of oyster spat and there is no doubt that on seriously understocked grounds, with brood oysters from previous spatfalls sparsely scattered over the cultivated portions of the fishery, and with intervening stretches of derelict ground, settlement in concentrations of commercial magnitude only occurs in the proximity of other oysters. To restore the derelict portions of these fisheries to a condition where heavy settlement of spat can occur, it is not only necessary to remove pests and to cultivate intensively, to clean up the cultch and to expose fresh surfaces for attachment, but also to sow with spat-shells or brood oysters to provide the necessary focus for gregarious settlement. This fact has been imperfectly recognised in the past and had led to much wasted effort on restocking without provision for additional cultivation.

Considering the oyster fisheries in Essex, a serious degree of understocking is evident in the Rivers Colne, Blackwater, Crouch and Roach, and substantial spatfalls are unlikely to occur except in the most favourable seasons. In normal years only a scattering of spat can be expected and we have recently shown (unpublished work) that even where conditions are apparently favourable, in that major pests are absent, a very high proportion of the settled spat, probably exceeding 90%, die during the first autumn and winter after attachment. On beds where pests, particularly Urosalpinx, are abundant and where silting is serious, the losses may be expected to be even higher.

In Cornwall the degree of understocking in the Fal is less serious and normal years give a sufficiency of spat for replacement but not for expansion; given adequate cultivation, which has not yet been achieved, substantial spatfalls may be expected to occur in this river regularly. In the Helford River, Cornwall, alone of British oyster fisheries, is there sufficient stock to give regular spatfalls; it is somewhat ironical that in this river the fishery depends mainly upon relaid French oysters, which thrive exceptionally, and little attention is paid to the systematic collection and cultivation of home-grown spat.

We are unable, as yet, to recognize a favourable season for settlement until after the event. Water temperature is certainly important but not all important. Recent work has convinced us that the view expressed in 1939 (Cole), that both the quantity and the quality of the nannoplankton organisms available as food supply might be important, is correct, and there is some evidence that on occasion the quantity or quality of the food supply is insufficient to give good growth and survival of larvae. As Korringa (1940) has pointed out, any factor, e. g., low water temperature or inadequate food supply, which causes the free-swimming development period of the larvae to be prolonged, increases the risk of the larvae perishing from other causes and of their being dispersed to unfavourable localities for settlement.

The importance of predators—ctenophores, medusae, fish larvae, which may vary greatly in numbers from year to year—has not yet been assessed, but in cool seasons when larval development is prolonged the losses they cause may be serious.

As far as British oyster beds are concerned, therefore, we are unable as yet to give a clear indication of the relative importance of the various factors controlling spatfall, but research has progressed so far that we may confidently expect to be in a position to advise the planters effectively on this problem within, say, another five to ten years.

The use of artificial collectors, such as limed tiles, to improve the settlement of spat on British beds has been widely advocated (Orton, 1937) and some trials have taken place both in Essex and Cornwall. To use such collectors effectively very sheltered con-

ditions are desirable, but suitable grounds appear to exist in some of the quiet creeks of Essex and on the up-river grounds in the Fal and Helford rivers in Cornwall. Sedentary organisms competing with oyster spat for food and space on the tiles seem to be a more serious problem than in France or Holland, particularly *Elminius modestus*, the barnacle, and the ascidian, *Ascidiella aspersa*, in Essex, and the tube-worm *Pomatoceros triqueter* in Cornwall. Some trials made a few years ago in the Helford River showed that a good spatfall could be collected, equal to a "good year" (DALIDO, 1948) in France, but competition from Pomatoceros was later very severe and the spat was stunted. Further work is needed, particularly in relation to the time of placing the tiles and the possibility of early detachment of spat before competition from sedentary organisms reaches a climax.

Tiles are relatively expensive to purchase and prepare, and the detachment of spat and its subsequent handling requires a lot of labour. In an effort to reduce these expenses it appears that the French planters are now beginning to experiment with coated egg-box partitions, as used successfully in Canada (NEEDLER, 1941) and elsewhere. We have tried these collectors recently in Essex with moderate results and further investigations may reveal methods of checking the settlement of competitors, particularly Elminius.

All artificial collectors so far employed require a considerable amount of labour; in Britain, where all the major companies are dependent on hired rather than family labour, this objection is particularly serious. It is possible, however, that such collectors may have their uses on some British beds and experiments are being continued in Essex and will later be extended to Cornwall.

Tiles have been successfully used by the Fisheries Department to collect spat in large concrete tanks at Conway for subsequent rearing on sheltered grounds in the Menai Straits, and the commercial possibilities of this method have been clearly demonstrated. Unfortunately the abnormal costs and difficulties of major constructional works prevent the wider extension of this method at present.

2. Abnormally Severe Winters.

There is a great lack of precise information on the effect of low temperatures on oysters. It is usual to talk of oysters as being killed by severe frost, but in fact there is little evidence of direct killing of oysters by low temperature in circumstances which were otherwise favourable. When very heavy losses have occurred they appear usually with the melting of snow and ice and seem to be the result more of a prolonged run of fresh water in the estuaries than of low temperature by itself. It seems as though oysters, perhaps weakened by a long spell of very low water temperatures, are unable to protect themselves from the adverse effects of low salinity and succumb in very large numbers. The finding of shells still containing meat, but with much sand or mud in the mantle cavity, suggests inability to close the shells sufficiently tightly to prevent the entry of silt disturbed and brought down by melting snow and ice. The freezing of oysters within ice-sheets deposited on the shores by the receding tide has been witnessed on many occasions, and such oysters may be carried away in large numbers when the tide returns.

Oysters laid on the Ministry's beds in the Menai Straits, in North Wales, and exposed by spring tides for 2—3 hours appear to be extremely hardy. There is never any serious general or local reduction of salinity on these beds and it was observed in 1940 and again in 1947, both exceptionally severe winters in North Wales, that the winter mortality was little if at all above the normal. In both years the coldest spell occurred during a period of spring tides and the oysters were exposed for several days to air temperatures in the region of —11° C.; the sea temperature was about 4° C. on each occasion. In 1940 after a night during which the air temperature fell to —12° C. and the oysters were fully exposed, low water being at approx. 6 a.m., a careful search of spat, brood and adult oysters was made without finding any weak or recently dead. It appears then that oysters may be resistant to low temperature if conditions are otherwise favourable. There is evidence that strains from various localities may differ in their ability to withstand severe winters, e. g. the Brittany oysters laid down in Kent and Essex suffered much more severely in 1940 than the native stocks (COLE, 1940).

Whatever may be the precise cause of death during exceptionally severe winters, there is no doubt that these constitute a very serious menace to oyster culture, particularly on the east coast, and another winter of a similar severity to 1939/40 or 1946/47 would put many planters out of business. The losses experienced in 1940 were surveyed by COLE (1940) and on very few beds were they less than 50%. In 1941 the losses were even higher, approaching 100% on up-river grounds covered by a small depth of water, and particularly subject to a reduction in salinity. Losses everywhere on the east coast reached 50% and the general average was approximately 75%. These losses were particularly serious since the beds in this area were already gravely understocked. In 1940 the beds in Devon and Cornwall escaped but in 1947 losses were experienced of about 20%.

To find a winter of comparable severity to the two under discussion we have to go back to 1895 and the occurrence of the 1947 debacle so soon after 1940 profoundly shook the confidence of the east coast planters. It appeared as though exceptionally severe winters, talked of as "occurring once a lifetime" were becoming a regular feature of our climate. Whatever may be the mathematical probabilities, the reaction of the major oyster companies in Essex and Kent, or rather those not restricted to a trade in genuine "Natives", was to seek grounds in the S.W. where serious winter losses are not a major hazard. It thus came about that three major companies traditionally associated with the east coast transferred the bulk of their business to Devon and

Cornwall while still retaining their grounds in Essex and Kent, but with reduced staffs. While this arrangement has reacted to the benefit particularly of the industry in the Fal, it has slowed down the rate of recovery of the Essex and Kent grounds. It has reacted particularly heavily on Whitstable which no longer can claim to be the most important centre of the industry; the Fal Estuary (including the Penryn and Percuel Rivers), and the Helford River, each now carry larger stocks of oysters.

In former years it was the custom on the east coast to place all oysters dredged up during the autumn and winter into shallow pits excavated in the saltings fringing the rivers and creeks. Oysters of various sizes—brood, half-ware and market grades—were placed in separate pits and in these pits they remained throughout the winter months, unless sold, being laid down again on the beds in March or early April. The use of these pits was universal on the east coast and there are remains of many thousands, although comparatively few are still in usable condition. Some on the shores of the River Roach, which are still in use, were figured by Bulstrode (1896, Plate No. 1) and the profusion of such pits alongside the Essex creeks is well shown by the aerial photograph of the creek mouths at West Mersea forming Plate XXIV of Stamp's (1946) "Britain's Structure and Scenery". This photograph shows the pits on Packing Marsh Island, to which reference is made below. Such wintering pits were never used extensively in Cornwall where losses by frost have never been serious.

It was the custom to take up all oysters each autumn from up-river grounds in Essex and Kent known to be subject to heavy losses during severe weather, but this practice fell into disuse as labour became more expensive and oysters less plentiful following the 1914—18 war, and the mortality which succeeded it. No doubt a succession of mild winters during the early twenties lulled the planters into a false sense of security. During the depression of the late twenties and early thirties the oyster trade was slack and expenses were cut, in consequence pits which were in need of repair were allowed to decay, the board sides rotted away or became dislodged and the tide broke down the walls of the pits and filled many in or demolished them altogether. Further, the technique of employing such pits to safeguard oysters in severe weather was lost and a new generation of oyster-men grew up without experience in their use. Small numbers of pits still remain in usable condition alongside most Essex rivers but they are now employed principally for the temporary storage of oysters before marketing. In the Blackwater some wintering pits are still employed by a few planters but there is much difference of opinion, and indeed uncertainty, regarding their proper management in severe weather. Some men attach great importance to the nature of the bottom, shram i. e. coarse shell gravel, or rammed chalk being most favoured, while concrete is held to be unsuitable. The proper depth of water to retain over the oysters, varying between little more than a foot and nearly three feet, is also in dispute, so too is the frequency with which the water should be changed. Formerly all pits were provided with a reservoir of water, either from another pit or from a "backwater" excavated in the marshes inshore of the pits, from which water could be obtained at neap tides or periodically changed, and this was used systematically, but most oyster-men are now at a loss when faced with questions regarding the technique of using such pits.

Recent experience with wintering pits has varied but on balance the oysters put into them have escaped with much smaller losses than on the neighbouring beds. Protected from serious falls in salinity and from heavy silting, oysters in pits are subject to low water temperature only, although deoxygenation may also be important. The temperature may fall to a minimum of —2° C. but the lower layer of water in the pit is sheltered by a layer of ice. It has been suggested that this ice should be broken "to allow the oysters to breathe", but more informed opinion suggests that the ice should not be disturbed. During the winter 1946/47 brood oysters placed in pits on Packing Marsh Island, West Mersea, referred to above, escaped with scarcely more than normal losses while similar oysters remaining in the creeks and main rivers suffered a minimum of 50% loss. On the other hand during the winter 1939/40 very heavy losses of larger oysters were experienced in pits on the River Roach, comparable with the mortality on the adjoining beds. Here it was alleged by some oyster-men that the treatment given was incorrect.

Careful research designed to elucidate the basic principles underlying the successful use of these pits, which are comparatively cheap to construct, is badly needed and forms part of the research programme of the Fisheries Department. Although the dredging up of oysters for pitting is rather a costly operation, it does incidentally enable such oysters to be concentrated later on good growing grounds, and ensures thorough cultivation. In the writer's opinion the successful reintroduction of the use of wintering pits on the east coast is essential to restore the confidence of the planters there in their ability to withstand the effect of severe winters; without such a technique at hand it is difficult to see how many of the shallow creek layings and the up-river beds, often extremely valuable as spatting grounds, can be restored permanently to a productive condition.

3. Imported Pests.

The two imported pests of major importance to British oystermen are the American Slipper Limpet (*Crepidula fornicata*) and the American Whelk Tingle (*Urosalpinx cinerea*). A third, the New Zealand and Australian barnacle *Elminius modestus* Darwin, has recently been recognized (Crisp & Chipperfield 1948 and Knight Jones 1948) and now occurs on all British oyster beds except those in the Menai Straits. It is dominant in the Essex rivers and constitutes a serious additional burden to the already handicapped

oyster planter in that area, since its settlement season coincides with that of the oyster. While it has been reported from Holland (Boschma, 1948) there are at present no records from France, where its presence might seriously hinder the collection of spat on artificial collectors. In Cornwall it is not as yet very widespread or abundant, but it occurs both in the Fal and the Helford River. It is too early to judge whether it will become so abundant on the cultch in this area as it is in Essex.

No method of preventing the settlement of Elminius on cultch or tile collectors has yet been found but its biology is being intensively studied both at Burnham-on-Crouch, Essex (Fisheries Department) and in the newly established laboratory for anti-fouling research at Brixham, Devon (Imperial Chemical Industries).

The American slipper limpet was introduced into this country with American oysters probably about 70 years ago, but Bulstrode (1896) when he surveyed the industry throughout the country did not allude to its presence. The first indication that it might become so abundant as to constitute a serious pest was given by Cooper (1905) and there is a record of law-suit at Burnham-on-Crouch in 1911 (Murie) in respect of alleged neglect of cultivation of an oyster bed based on the prevalence of slipper limpets on the ground in question. There seems no reasonable doubt that Crepidula was disseminated from Brightlingsea, Essex, and spread from there to the other centres of oyster culture in Essex. There has always been a considerable traffic in oysters between the Essex producing grounds and Whitstable and it would not be very long before Crepidula was transferred.

It was formerly the custom for some of the Essex and Kent planters to transfer oysters for wintering to the creeks around Hayling Island, Portsmouth and at this time (before the 1914—18 war) an Essex Company also held the rights in Bosham Creek, slightly further to the east, and it appears that slipper limpets were transferred to these creeks from Essex or Kent. They have since extended steadily along the south coast and have now reached the Torquay—Paignton—Brixham area in S. Devon. Small numbers have also been found during the last three years in the Fal and the Helford Rivers.

To the north, Crepidula has extended as far as Blyth, Northumberland, a few miles from the Scottish border (Bull, 1939) where there is definite evidence that large quantities were brought from the Blackwater on the bottom of a German vessel broken up in the yards. This evidence of transference on the bottom of a ship is of importance since Korringa (1942) states that it is never carried in this way.

It is very difficult to explain the occurrence of Crepidula in the Fal and Helford Rivers unless they can be transferred on ships, since none have been found between Brixham and Falmouth, a distance in a direct line of about 50 miles. Since the intervening stretch includes all the grounds worked from the Plymouth Laboratory of the Marine Biological Association, it is unlikely that Crepidula would pass undetected. Falmouth is a dock-yard town and a considerable number of ships pass through per annum and it is certainly possible that Crepidula may have been introduced in this manner. Oysters are relaid annually in the Helford River from the Fal and Crepidula may have been carried in this way from the Fal, although there is also the possibility that it may have been brought on American warships, which entered the mouth of the Helford River during the war period, or on a yacht laid up on the south or east coast.

Although Crepidula has been recognized as a serious hindrance to oyster culture for at least 30 years, very little work has been done on its biology or ecology; apart from the studies of feeding and sex change by Orton (1912) and Coe (1936) there is nothing on which to base research designed to elucidate methods of control. We have, however, now taken steps to remedy this defect and a comprehensive study of its growth, settlement, breeding and distribution in Essex is in progress.

It is claimed that in Holland a reasonable degree of control of Crepidula has been achieved, principally by the manufacture of a valuable product from the meat, thus making it worth while for the oyster-men to collect and bring ashore Crepidula. It is also said that where limpets are fairly thin and oysters have been taken up, the destruction of a high proportion of the remaining colonies can be arranged by temporarily leasing the ground to mussel cultivators, who plant it thickly with seed mussels, thus smothering most of the limpets.

Neither of these methods is at present feasible in Britain since all efforts to find a remunerative outlet for slipper limpets have failed and there is no interest in mussel culture in the areas where Crepidula is abundant, in fact mussels are regarded as a minor pest and are discouraged. It is possible that a market may eventually be built up for slipper limpets as a supplementary protein poultry food and effort along these lines is being continued.

The most hopeful method of control lies, however, in the development of mechanical dredging gear. At present one-man hand hauled dredges are used on all British oyster beds, although a hand operated winch of a very simple type is used in the river Fal, from rowing boats, and in this way the width of the scythe of the dredge can be increased to 3 feet from the normal 2 ft. 3 in.

Power-operated dredges have been used for many years in the Netherlands and also in America but have not been generally adopted in France. It must be remembered that the conditions under which these large dredges have been employed have no counterpart in England except perhaps at Whitstable. The Dutch and American oyster beds are extensive and situated in open waters where it is easy to manoeuvre comparatively large vessels. Further the bottoms are for the most part hard and shelly and well suited to withstand the adverse effects of heavy dredges. Many of the British beds lie in narrow somewhat

muddy creeks in which it is impossible to manoeuvre anything larger than a small launch and, indeed, some layings have not sufficient depth of water over them at low water of spring tides for motor vessels. The bottom in most of the creeks of Essex and Kent, and on the up-river layings in the Cornish estuaries, consists of mud with a small proportion of sand and variable quantities of shell cultch. It has yet to be proved that heavy power-hauled dredges can be safely used on such tender soils and the caution of the English planter, with a small area of cultivated ground, is understandable. The majority of British Oyster Companies, however, hold the rights over extensive areas of grounds, measured in hundreds of acres, and in the major rivers of the east coast, the Colne, the Blackwater, the Crouch and the Roach and on the Whitstable Flats it is reasonably certain that large dredges, perhaps of modified design, could be safely used; indeed there is no other way in which the vast areas of semi-derelict ground can be cleared of slipper limpets and rubbish and brought into a fit condition for replanting.

The Fisheries Department of the Ministry of Agriculture and Fisheries has recently equipped a motor dredger with a winch and gallows of experimental design and work has begun, with large dredges of the Dutch pattern, on the reclamation of derelict beds in the River Roach. If this work is successful, and first results are promising, it is hoped that the major oyster companies in Essex, Kent and Cornwall can be persuaded to fit the necessary winches and gallows, or davits, to tackle the large areas of limpet infested ground that they now hold. It is recognised that this task may be beyond the powers of the companies, unaided, since no returns would be obtained from the work during the first two or three years, that is unless a market can be found at a remunerative price for Crepidula, and this now seems unlikely. Some Government assistance may be needed, perhaps in the form of grants to assist in meeting the rather high initial cost of the mechanical equipment needed, or in the form of grants per acre for clearing and replanting oyster bottoms approved as suitable for reclamation. Our recent studies of the rate of re-establishment of slipper limpets on cleared ground suggest that, provided the initial clearing is done effectively, it should be possible to maintain the ground reasonably free from limpets by normal dredging, particularly if the system of clearing all grounds completely of oysters, and to a large extent of cultch, in rotation, is adopted. This implies culling the catch ashore, rather than on board as is now the usual practice, but this would in many ways be a desirable development as it would enable the cold and often rather unpleasant task of culling to be carried on effectively indoors independent of weather conditions.

The American whelk tingle, Urosalpinx, is in many respects a more serious pest than Crepidula, although the need for more active measures of control where it is prevalent is not as clearly appreciated as it should be. There is no doubt that despite warnings (Cole 1942) Urosalpinx is becoming more prevalent. It is confined so far as we know to Essex and Kent, but does not apparently thrive as well on the Whitstable Flats, which have a hard sandy and shelly bottom, as it does in the Essex rivers. Much of the damage that this pest does unfortunately passes unrecognized, since the shells of small spat up to thumb nail size, which are its chief prey along with barnacles, are easily swept off the cultch and broken up. Further there is evidence that Urosalpinx destroys annually very large numbers of tiny spat within a few weeks of settlement. In the Essex rivers 75% would probably not be an over estimate of the percentage of spat destroyed during the first year of life. Although Urosalpinx will on occasion attack adult oysters, both English and Portuguese, it is a serious pest only of spat and brood oysters up to 2 years of age. Urosalpinx was apparently introduced into this country with American oysters about 30 years ago but was confused with the native drill *Ocenebra erinacea* at first (Orton, 1927); the latter now seems to be extinct on the East Coast following the severe frosts of 1940 and 1947 (see Orton, 1931 & Cole, 1942).

At present control of Urosalpinx comprises removal of adults and spawn during dredging. Small tingles drop through the dredge rings and very few are collected. This is an inadequate measure of control and Urosalpinx is increasing in Essex. Traps such as have apparently been used successfully in America (Galtsoff, Prytherch and Engle (1937) and Federighi (1931)) have been found to be ineffective in Essex and also in Canada (Adams, 1947). The density of drills on the traps is not significantly higher than on the surrounding bottom as tested by dredging. Special dredges, releasing oysters, but retaining drills, may have some application but it will be necessary to develop a special pattern applicable to British conditions.

It is found that Urosalpinx does not occur in any significant quantity on stretches of clean muddy bottom without a top layer of cultch and, generally speaking, derelict grounds over-run with Crepidula—the "mud and limpets" of the Essex dredgermen—carry few tingles. The conditions that seem to favour Urosalpinx occur also on well cultivated creek layings. It is possible that by cultivating intensively patches of ground, surrounded by broad strips of clean mud, the migration into the cultivated areas of tingles from adjoining grounds might be prevented. Another possible method of control that is being investigated is the multiplication of final hosts of certain trematode parasites which cause castration.

This pest presents an intractable problem and it may well be that the most effective method of control will prove to be intensive dredging with special equipment during the early summer months when the drills are spawning. At this time a very high proportion of females is collected by the dredge (Cole, 1942), possibly due to the ease with which the male is detached from the cultch compared with the female,

resulting in the loss of males when the cultch is disturbed by the dredge. Spawn is usually deposited on cultch or other objects large enough to be retained by the dredge and intensive dredging of heavily infested ground during the period between spawning and hatching of the egg-capsules will always be an important measure of control.

4. Disease.

In the years 1920—21 there occurred in Europe a widespread and devastating mortality among oysters. The losses were exceptionally severe throughout Britain but more especially in Essex and Kent. A thorough investigation was made by ORTON (1924), who however suffered from the inevitable handicap of starting his investigations when the mortality was already on the decline. No causative organism was discovered but it was proved that the popular belief that the mortality was due to the dumping of unwanted explosives was without foundation. It has recently been suggested by GAARDER and ALVSAKER (1941) that the losses were due to exceptionally unfavourable environmental conditions persisting over several years, but this explanation cannot be accepted by anyone with memories of the vast quantities of dead oysters which appeared with relative suddenness on most British beds. The effect of this great mortality is evident in the returns from all British fisheries (see Tables 2 and 3) and the industry has never recovered the lost ground. Some recovery took place in the latter half of the inter-war period but this was more than wiped out, at least in the east, by the effects of the severe winters of 1940 and 1947. There is always the fear that a similar mortality, unheralded and equally devastating, may reappear on British beds and the knowledge that somewhat similar unexplained epidemics have occurred in Australia (ROUGHLEY, 1926) and Canada (NEEDLER, 1941) does not make for confidence. The devastated beds in Canada were however repopulated by apparently resistant strains and something of the sort may have occurred on British beds, since slightly abnormal losses are still occasionally experienced which are not easily explained except as the result of mild epidemics. The shell disease which is so prevalent in the Netherlands has never appeared in this country although Dutch oysters are regularly imported. They come, however, as ware oysters to be sold direct for consumption and are not now usually laid down on English beds.

5. Pollution.

The advance of industrialization and the spread of housing estates, accompanied as they are by increasing industrial and sewage pollution, have made it impossible to continue oyster culture on certain beds which were still productive at the beginning of the century. The spread of industry is particularly harmful in that it provides new sources of work to inshore fishermen, often at more remunerative rates. In this category we must include dockyards, both civil and naval. The once flourishing oyster beds in the Tamar at Saltash, Plymouth, have disappeared during the last 30 years, partly as a direct result of dredging to deepen the river for naval craft, and partly following great expansion of activity in the dockyards with accompanying pollution, but also by the absorption of the inshore fishermen into the industrial community. Some suitable oyster ground remains but the few inshore fishermen left are no longer interested in oyster dredging. In the neighbourhood of Portsmouth the position is much the same and the formerly much used beds in the creeks around Hayling Island ceased production after the 1914—18 war. The south coast oyster beds generally have suffered severely from the increasing sewage pollution which, combined with the prevalence of slipper limpets and the conversion of fishing ports into holiday centres, has resulted in the abandonment of once productive fisheries at Emsworth, Bosham, Chichester and Poole. There is now no major oyster fishery on the south coast east of Devon, the River Yealm, a few miles east of Plymouth, being the first. This should be compared with BULSTRODE's 1896 list of:—Southwick, Shoreham, Bosham (all in Sussex), Hayling Island, Emsworth Creek, Wooton Creek, Medina River, Hamble River, Beaulieu River (in Hampshire, including the Isle of Wight) and Poole and Wyke Regis (Dorset). Some of these fisheries are still capable of restoration—industrialization and housing development have not proceeded so far as to make them unsuitable for oysters—but in practically all cases provision would have to be made for the cleansing of the oysters from sewage pollution.

Sewage pollution is increasing and there is no doubt that the proportion of the population served by water carriage systems will rise steadily during the next ten years as the construction of new plants becomes possible. Unfortunately there is still a tendency on the part of coastal authorities to regard the discharge of crude sewage into estuarine waters as a reasonable practice and this is a matter which, in the interests of fisheries generally and shell fisheries in particular, should receive attention at the highest levels. The substitution of full treatment for crude discharge would bring about a positive improvement in the conditions of many estuaries and would help to redress the adverse effects of extended housing development. The sterilization of sewage is again receiving attention but most suggested methods would result in the discharge of a toxic effluent in some ways more dangerous to shellfish than the untreated sewage.

Fortunately there are still estuaries and inlets free from serious contamination in the remoter parts of East Anglia and the South West, and present-day planning powers seem to be sufficient to enable the fishery interests to resist any developments calculated to damage their interests.

The purification of oysters from sewage pollution has been successfully dealt with at Brightlingsea, Essex, by adapting the Conway technique to the

special needs of oysters. The principal adaptations are the slight warming of the water during the winter months to increase the rate of filtration by the oysters and a special hosing device to overcome the difficulty encountered in cleansing externally flattened instead of rounded shellfish. Unfortunately while this cleansing process seems to meet the needs of the planters of Portuguese oysters and is unassailable bacteriologically, there is an ineradicable prejudice against any process using chlorine, which has prevented the extension of this system to fisheries producing high quality natives. It is alleged that oysters are affected by the process, by the warming of the water, and that they taste of chlorine. Despite careful tests none of these alleged defects in the process have been substantiated; nevertheless the prejudice is no less strong now than it was 10 years ago and it would be unrealistic not to recognize its importance. The result has been the private development of an alternative method of purification based on a closed water system sterilized by the addition of ozone from a proprietary ozonizer. The system has not received official approval and cannot be used to cleanse oysters taken from a fishery officially closed on Public Health grounds under statutory powers, nevertheless a very substantial proportion of the oysters marketed in this country pass through plants of this type.

Such controlled bacteriological tests of the oysters passing through these plants, and physiological tests of functioning among the shellfish undergoing treatment, as have been made independently have not always been satisfactory and it is freely admitted that heavy losses may occur as the result of slight over-dosing with ozone. The lack of provision for slight warming of the water during very cold weather, or alternatively for extending the period of purification, does not inspire confidence in the functioning of these plants and the likelihood of their receiving official sanction is rather remote. A thorough investigation of the value of ozone in the cleansing of oysters is however overdue, since the commercial development of these small scale cleansing plants demonstrates the need for a cheap and effective system to deal with the output of an individual firm. Although the objections to the private operation of cleansing plants by oyster planters still remain as stated by Dodgson (1928), the provision of an adequate system of inspection and testing of private plants is by no means impossible. Where isolated fisheries occur, controlled by a single firm, and there are several of these, it is difficult to see how any independently controlled cleansing plant could be provided and in such cases the onus for the delivery of a clean product must rest on the oyster planters.

There is an urgent need for the provision of a simple, cheap and reliable method of purification for use on oyster fisheries where, although the risk of sewage contamination of oysters is small, it cannot be completely eliminated. This may be said to be the general condition of the majority of British beds not already closed on Public Health grounds. Sewage is present in many estuaries but is usually discharged many miles from the nearest beds, and is greatly diluted. Public Health authorities are naturally reluctant to give a "clean bill" to such fisheries and the provision of some extra safeguard in the form of a simple method of treatment would materially assist sales. Such a process must be cheap to run and low in capital cost, and experience with systems involving chlorination of water suggests that prejudice against them will not be easily overcome, and that some other method is required.

There is a good deal of evidence for the view that such slight pollution may be readily eliminated by the proper use of efficient storage pits, excavated on the shore out of reach of the tide, to a depth of about 2 feet, 6 inches, and filled by pumps at high water. Oysters retained in such pits for four days have been found to get rid of all contamination even at temperatures as low as 5° C. By siting the pits as far away from actual sewer outlets as is reasonably practicable, and by filling only at high water, recontamination with sewage organisms may be avoided. Using a series of such pits, in regular sequence, successive batches of oysters may be prepared for market. Under such conditions oysters remain healthy almost indefinitely during cool weather; the water may be changed weekly if desired, but a further two days should be allowed to elapse after renewal before any oysters are removed for market. The suggested period of cleansing—4 days—appears to offer a sufficient margin of safety even during the coldest weather when the rate of filtration of water by the oysters is reduced to a minimum. It is important to realise in assessing the performance of oysters in such cleansing pits, that the filtration of water by oysters does not cease at low temperatures but is merely gradually reduced as water temperature falls to freezing point. The final hosing of oysters before dispatch to market should be done either with fresh water, or if this is considered undesirable, with sea water drawn from a separate concrete tank in which it has been allowed to stand for several days; the partitioning of this tank would ensure a continuous supply.

I have dealt above in some detail with the problem of cleansing cheaply and simply, in a manner unobjectionable to the trade or public, of oysters subject to a risk of slight sewage pollution, because I regard the provision of such cheap and efficient cleansing facilities as a matter of great urgency. Without such plants, preferably independently operated, to give confidence to the consuming public, a large expansion of the British oyster industry is hardly possible.

Marketing.

It is impossible to give a comprehensive survey of the difficulties facing the British oyster planters without making some reference to problems of marketing, particularly as related to the importation of foreign oysters.

At present most firms market four grades of flat

oysters (*Ostrea edulis*) which differ widely in price; representative figures for the four grades during the 1948/49 season were 60/-, 52/-, 42/- and 30/- per 100. It may be said with some truth that all but the lowest grade were destined for what may be called the luxury market, comprising large restaurants, high grade hotels, oyster bars in large cities particularly London, Clubs and banquets. Only third and fourth grade oysters would be offered for sale in substantial quantities in retail shops and very few of the best grade oysters would be sold outside London and a few other large cities. The majority of the public do not see a flat oyster from one year's end to another but may eat small quantities of Portuguese at the popular holiday resorts.

The very highest grade genuine 'Native' oysters, i. e., those spatted and reared in Essex or Kent, at the moment very scarce, realise considerably higher prices, for example the Colne Fishery Board, in its accounts for the year 1947/48, claims to have sold 153,247 oysters at an average price of 89/- per 100. These oysters have a very high and jealously-guarded reputation which is generally considered to be thoroughly deserved and the stocks of natives of the particular type associated with the River Colne and Pyefleet have been kept pure from time immemorial; nevertheless it must be obvious to everyone that the market for oysters at such prices is severely limited and likely to remain so. There are one or two more beds on the Essex coast on which 'Natives' are cultivated exclusively, and to these planters and to the Colne Fishery Board the maintenance of very high prices is a matter of great interest, especially since genuine 'Natives' of good quality are exceedingly scarce. Since the majority of British oyster fisheries are very seriously understocked and there is no rich source of British brood oysters for replanting, the importation of foreign flat oysters for restocking cannot be avoided if the British beds are to recover. Brood oysters (flat) could only be safely obtained from France or Norway because of risks of disease or pest infestation from other sources. Spat might be available in fair quantities from Norway but the results of trials in progress in the Menai Straits are not encouraging; the spat is so small, light and thin-shelled on arrival that it needs protection both from strong tides, which may sweep spat away from the beds on which it has been laid, and particularly from American tingles. It is doubtful indeed whether any use can be made of this Norwegian spat until the American tingle problem has been solved, as the thin shells offer practically no protection and losses under present conditions would be very severe. We are therefore thrown back upon the importation of French brood oysters; these have done exceptionally well in the past in Devon and Cornwall and meet the requirements of all but the most select trade which still clings to the genuine 'Native'. On the east coast, experience with Brittany oysters has not been so happy, losses have frequently been severe and there is a very general complaint that they do not fatten so well as the native; this complaint has not yet been substantiated by controlled experiments. On the other hand there is little doubt that French oysters breed successfully on all British beds, and for restocking purposes I regard them as quite satisfactory. The fear that, by the introduction of French oysters for breeding on grounds formerly reserved for natives, the fine qualities of the latter will be diminished, is probably unfounded, since the produce of these imported oysters and the native stocks is likely to assume the characteristics of the locality. The subjects of race variation in oysters and resistance to frost and low salinity are however practically closed books and it would not be advisable to be too dogmatic.

It is doubtful whether the grounds in the River Colne and in the other haunts of the true native will recover without extensive restocking, and it appears that, to survive, the relaying of French oysters on these grounds too is now a necessity. This necessitates a revolutionary change of attitude, since no foreign oysters have ever been laid on these grounds, but the total production of the Colne Fishery Board, which controls probably about 1,000 acres of oyster bottom in the River Colne and Pyefleet, only amounted to 153,247 in 1947/48 and the immediate prospects are no brighter. Despite spectacular recoveries in the past, when stocks were low, it is not believed that this is possible now as there is a new factor tending to reduce the chances of a successful spatfall, viz. the universal prevalence of Crepidula on the east coast beds.

To guard against the possibility that the desirable characteristics of the true native may be lost, genetical research should be initiated as soon as possible with the aim of selecting and fixing quick growing, frost resistant strains of superior marketable quality.

Conclusion.

Some of the major problems of the oyster industry enumerated above, can be solved by the trade unaided. Among these we may include the necessity for substantial restocking with French oysters, and the achievement of a widespread increase in the intensity of cultivation of the beds. Others require the close co-operation of the scientist and the oyster planter. These include the development, and adoption where practicable, of mechanical methods of dredging and handling oysters; the employment of these methods in the reclamation of derelict ground and the re-introduction of the use of wintering pits so to avoid severe losses during hard winters on the east coast. A few, such as the elucidation of the causes of spatfall failures, the development of artificial collectors, the evolution of special methods of controlling pests and the development of new cleansing techniques, require extended research. To facilitate this research the Fisheries Department of the Ministry of Agriculture and Fisheries has recently established a new laboratory at Burnham-on-Crouch, Essex, in the centre of the oyster producing area, where the

major problems facing the trade are already receiving attention. This station will, in due course, undertake research on other inshore species of importance but at present attention is concentrated on oyster problems. For this purpose the station has been equipped with a motor-dredger and controls oyster layings of a representative character in the Rivers Crouch, Roach and Blackwater which together provide suitable conditions for an attack on all the major problems. The first results are now coming from this new venture and we may look forward confidently to further discoveries and developments of great interest to all associated with the oyster industry.

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2.

Scottish Research on Oyster Fisheries.

By

R. H. Millar

Scottish coastal waters formerly supported a large natural population of the European flat oyster, *Ostrea edulis* L. and oyster fishing was an industry of some importance. Continued over-fishing reduced the numbers of oysters below the level at which commercial fishing was economic and now only one small fishery remains at Loch Ryan on the south-west coast.

Investigations are being carried out by the Scottish Marine Biological Association to discover the best methods for reviving oyster fisheries round the Scottish coasts. The programme, which was started in 1946, has two chief aims:—

(1) the investigation of problems in oyster breeding, and

(2) the survey and testing of shores to find places where growth and survival of oysters are favourable.

(1) Breeding problems. Experiments were first carried out in a semi-enclosed part of a sea loch in the west coast of Scotland to find if a breeding centre could be established there. Hydrographic conditions were found to be suitable but the abundance of the ascidian *Ascidiella aspersa* (Müller) determined that all surfaces exposed for the settlement of oyster larvae were rapidly covered by ascidians. Settlement and survival of oysters were not possible under these conditions and the site had to be abandoned.

In 1948 experiments were made in breeding oysters in an outdoor concrete tank of 240 m.^{3} capacity. After the tank was filled with sea water, in May, 400 oysters were placed in the tank and these liberated abundant larvae which produced two spatfalls, a light one in August, and a heavy one in September. The summer of 1948 was cold and it was necessary to raise the temperature of the sea water in the tank by covering it with a thin layer of fresh water.

Experiments have also been made during 1948 and 1949 in breeding oysters in a deep quarry flooded by the sea. 2,000 oysters were suspended in wire cages in this quarry, and the larvae produced resulted in a spatfall in August 1948.

During these breeding experiments an attempt is being made to find what factors control the survival and growth of the oyster larvae. Observations are being made on the salinity, temperature and pH of the water; on the concentration and kind of flagellates and algae of 10 μ and less in diameter which may serve as food for the larvae; and on the numbers and growth of the larvae.

(2) A survey is being made of part of the west coast of Scotland to find places most suitable for laying oysters. Selected parts of the shore are tested by laying on them a few thousand 2- or 3-year-old oysters and measuring their growth rate, condition, and survival.

It is hoped that this programme of research will find the best methods of providing an adequate supply of young oysters and the best places for growing them rapidly to marketable size.

3.

La Situation de l'Ostréiculture dans le Bassin de Chasse d'Ostende de 1939 à 1948.

Par

Raoul Halewyck et Eugène Leloup

A la fin de l'année 1938, l'utilisation du bassin de chasse d'Ostende s'annonce favorable pour la culture intégrale de l'huître plate.

En Janvier 1941, pour des raisons militaires, les autorités occupantes font mettre à sec le bassin par temps de gelée et construire une digue qui empêche encore actuellement la vidange du bassin et le renouvellement de l'eau.

De 1940 à la fin de 1944, l'exploitation ostréicole ne peut avoir lieu. Elle reprend au cours de l'hiver 1944—1945.

Quelques huitres ayant survécu au désastre de 1941 avaient assuré une production telle que tous les supports immergés sont couverts de jeunes huîtres. Au cours des années 1944—1946, les huitres restent maigres, sous-alimentées.

A cause de l'évaporation, le taux de salinité augmente dans cette masse d'eau non renouvelée et dès 1947, l'exploitant utilise désormais le bassin de chasse comme réserve destinée à reparquer des huîtres plates et portugaises importées.

En 1947, des fortes températures estivales (18—28° C.) et une salinité comprise entre 28 et 34 $^0/_{00}$ favorisent une reproduction abondante. Par contre, au cours de l'été 1948, la température s'est rarement élevée au dessus de 18° C. pour une salinité de 27·56 à 29·70 g/NaCl $^0/_{00}$, et les huîtres se reproduisent mal. Les plates ne poussent que faiblement, mais les portugaises deviennent d'une belle qualité.

A la fin de l'année 1948, la reproduction des huîtres plates et portugaises réussit dans le bassin à cause de l'élévation du taux de la salinité de son eau. Les huîtres plates n'y engraissent pas mais les portugaises prospèrent.

En résumé, en Belgique, le développement de la culture de l'huître plate, la seule intéressante pour ce pays, ne peut reprendre dans le bassin de chasse d'Ostende qu'après la remise du bassin dans son état primitif.

4.

Les Huîtres des Côtes Françaises
Ostrea edulis et *Gryphoea angulata.*

Par

Louis Lambert.

I. Les Gisements naturels. La Pêche.

Les bancs d'huîtres plates (*Ostrea edulis*) formaient jadis un cordon ininterrompu sur toutes les côtes de France.

Quelques chiffres donneront une idée des quantités d'huîtres pêchées jadis sur les côtes Françaises. A la fin du XVIIIème siècle et au début du XIXème, les pêcheurs enlevaient des seuls bancs de Cancale et Granville au minimum cent millions d'huîtres par an; leurs bateaux pêchaient du 1er Septembre au 1er Avril sans discontinuer. La destruction du naissain et des petites huîtres par les dragues très lourdes que l'on employait alors était plus grand encore. L'exportation, de 1772 à 1775, atteignit le chiffre de 293 millions. En 1775, notamment, 234 bateaux Normands et 104 Anglais emportaient de la Baie de Cancale 95 millions d'huîtres.

Il n'y avait plus là exploitation, mais pillage et destruction.

Certaines causes naturelles, nommées par les pêcheurs "maladies" ou "mortalité", qui, malgré les efforts des biologistes, n'ont pû être élucidées, ont achevé l'oeuvre de l'homme. Des gisements si florissants de jadis, il ne reste que débris.

Quelques-uns se reconstituent lentement; pour d'autres, l'Administration a tenté de les rénover, mais on ne peut plus guère espérer revoir les magnifiques pêches d'antan.

Un hasard heureux a compensé en partie cette disparition.

Depuis 1867, en raison de la pénurie de notre élevage d'huîtres indigènes, les parqueurs d'Arcachon faisaient venir de l'embouchure du Tage, des huîtres Portugaises; les importations atteignirent, à partir de 1875, 25 à 30 millions de mollusques par an. Or, il arriva qu'au début de 1868, un navire ayant pris à Lisbonne un chargement de gryphées pour Arcachon, fut forcé par la tempête de se réfugier en Gironde et d'y séjourner quelques temps; sa cargaison s'avaria et on la jeta par dessus bord, entre Richard, Talais et le Verdon, sur la rive gauche du fleuve. Toutes les huîtres n'étant pas mortes, les survivantes se multiplièrent bientôt et couvrirent les rochers de la Gironde dès 1868, les côtes de la Rochelle en 1875, celles de l'île de Ré en 1878. Le développement des huîtres Portugaises fut prodigieux vers 1907 sur la côte de la Charente-Inférieure. L'invasion s'arrêta vers le Havre du Payré, en Vendée. La Portugaise était restée dans ces régions depuis lors, y occupant la place de la plate disparue, mais les ostréiculteurs Bretons, spécialistes de l'huître indigène, craignant toujours sa venue, un décret interdit en Février 1923 son introduction par les parqueurs au nord de la Vilaine (sauf quelques dérogations pour le nord-ouest, région plus froide, et quelques points isolés).

La crainte n'est pas vaine, car en 1932, les roches des côtes du sud de la Loire se sont couvertes de gryphées. Les gelées d'hiver en ont détruit la plus grande partie, mais j'ai trouvé depuis des spécimens vigoureux dans le lit de la Loire et on peut affirmer que la Portugaise ne finira pas par s'acclimater et continuer sa marche vers le nord.

Pour le moment, la limite qui sépare les gisements naturels d'huîtres plates et de Portugaises est à peu près la même que celle fixée un peu arbitrairement aux ostréiculteurs.

Les gisements d'huîtres plates sont tous au nord de la Loire; les gisements de Portugaises occupent principalement les roches calcaires de la Vendée et surtout de la Charente-Inférieure, puis l'embouchure de la Gironde. Il existe un petit gisement à l'entrée de l'Adour.

L'exploitation de ces gisements est réglementée: les gisements sont classés; chaque année, une commission de visite les examine et conclut à l'ouverture

ou à la fermeture de la pêche; dans le premier cas, un arrêté autorise celle-ci pendant un certain laps de temps qui varie de une heure à plusieurs mois et peut même atteindre toute l'année.

Toujours, l'ouverture des gisements de plates est courte et se limite à quelques heures.

La pêche, le triage, le nettoyage sont surveillés par des agents de l'État, les garde-pêches qui disposent de bateaux de différents tonnages.

En général, les pêcheurs sont tenus de rejeter sur les gisements les petites huîtres et les collecteurs naturels en bon état, de ramener à terre les coquilles pourries et les divers animaux destructeurs de l'huître. L'exploitation des gisements de plates se fait surtout en bateau, à la drague. C'est un chalut très réduit constitué par une armature en fer qui racle le fond de la mer, prolongée par une poche en filet ou en mailles métalliques dans laquelle s'accumulent les coquillages détachés du fond.

Le rendement de ces gisements naturels à peu près ruinés est assez faible. Plusieurs tentatives de reconstitution ont été faites, mais il semble que l'avenir de l'huître plate soit aujourd'hui confié à l'ostréiculture.

La Portugaise est pêchée en bateau, mais surtout à pied. Espèce côtière, elle est plus accessible aux pêcheurs à pied que l'huître plate. Seuls, certains gisements de la Gironde sont exploités à la drague; pendant plusieurs mois de nombreux bateaux participent à cette pêche dont le rendement en huîtres se chiffre par centaines de millions.

Elle se fait sur toute la côte, en général, de Novembre à Avril.

Le détroquage, qui consiste, ici, à séparer les huîtres les unes des autres et le triage doivent être faits à des endroits fixés. Les quantités d'huîtres Portugaises récoltées par les pêcheurs sont considérables.

Le rendement d'une campagne a pu être évalué à 300 millions d'huîtres pour la pêche en bateau et près du double pour la pêche à pied.

II. L'Ostréiculture.

A. La récolte du naissain — les collecteurs.

Du dépeuplement des gisements naturels d'huîtres plates naquit la véritable ostréiculture qui consiste à recueillir le frai d'huîtres (naissain), à l'élever, à engraisser l'huître adulte et à la préparer à l'expédition aux consommateurs.

Le premier objet de l'ostréiculture est donc de fournir au naissain, pour le capter, des supports appropriés, nombreux, à grande surface, propres, des "collecteurs".

A première vue, tous les matériaux semblent adaptés à cet emploi, car, dans la nature, on trouve des huîtres fixées sur les corps les plus divers, mais la très grande majorité des larves d'huîtres se perdent faute de support approprié. C'est là une des causes du dépérissement des bancs naturels. On a essayé d'y obvier en France en organisant le nettoyage de ces bancs, en exigeant des pêcheurs le respect des collecteurs existants, l'apport de collecteurs nouveaux. Sur certains bancs, l'Office des Pêches fait jeter des coquilles propres, des débris de tuiles, d'ardoises, etc., mais on a surtout organisé sur des concessions particulières le captage des naissains émis par les huîtres des gisements et celle des parcs que beaucoup d'éleveurs ont soin de garnir d'huîtres adultes. L'idéal serait, certes, de tout capturer et on a tenté la fécondation artificielle, la reproduction en bassin. Ces tentatives, sans avoir échoué, n'ont pas obtenu tous les résultats escomptés. Actuellement, le captage se fait en grand dans les rivières, dans les baies, tous endroits plus ou moins abrités.

Les collecteurs varient suivant les régions; dans celles où le captage est devenu une véritable industrie, on emploie surtout la tuile de terre cuite en forme de demi-cylindre aplati, enduite de chaux seule ou d'un mélange de sable et de chaux. Les dispositifs sont adaptés à la nature des fonds.

Dans le Bassin d'Arcachon, où le sol est ferme, on les dispose en ruches; ce sont des grandes caises à claire-voie dans lesquelles on empile des tuiles de grande taille jusqu'à concurrence de 100 à 120 par ruche.

Ces tuiles sont préalablement chaulées au moyen d'un mélange de deux parties de sable et d'une de chaux. L'enduit ainsi formé est épais et rugueux. On capture de la sorte, suivant les endroits, les naissains de plates ou de Portugaises.

Le nombre des tuiles mises à l'eau est de l'ordre de sept millions; le nombre des petites huîtres capturées évalué à un milliard.

En Bretagne, zone réservée à la seule huître plate, le sol est plus vaseux, les collecteurs doivent être surélevés; on assemble sur un piquet, au moyen de fil de fer, les tuiles qui sont dans ce but percées de deux trous, sur 6 rangs opposés de 2 tuiles, en bouquet ou champignon; le bouquet ainsi formé est plongé dans un lait de chaux, puis séché à l'air. On enfonce le piquet dans la vase.

Le nombre de tuiles utilisées dépasse dix millions.

D'autres collecteurs sont employés concurremment à la tuile:

Dans la rivière d'Auray, on pose encore quelques plateaux de bois chaulés. Çà et là, des chapelets de coquilles chaulées ou non sont disposés sur des piquets; enfin, les débris de tuiles sont semés sur les parcs à naissain.

Dans le centre-ouest, sur les côtes de la Rochelle et de l'île de Ré, on aligne dans les parcs des quartiers de roc ou de grosses pierres qui forment des sillons.

Près de l'embouchure de la Charente et dans la

région de Marennes Oléron, on plante dans le sol vaseux des tiges de noisetier ou de chataignier. Elles forment de véritables forêts de plusieurs kilomètres de longueur. C'est le "piquetage".

Dans la région de Marennes, on forme avec des coquilles et des débris d'ardoise des chapelets qui sont comme en Bretagne ou à Arcachon disposés au dessus du sol au moyen de piquets, jetés sur le sol même, ou disposés en "berceaux". Des tuiles ou des ardoises sont alignées sur le sol.

Enfin, on a vu apparaître au cours de ces dernières années des collecteurs en fibro-ciment, d'autres formés de coquilles de coques (*cardium edule*) enfermées dans des casiers ou des sacs grillagés, des agglomérats de matériaux inertes noyés dans un liant calcaire, enfin des collecteurs en carton analogues aux boîtes employées pour l'expédition des oeufs, chaulés et groupés dans des armatures en grillage à larges mailles ou en bois.

Le point délicat est de déterminer exactement le moment de la pose de tous ces collecteurs; placés trop tôt, ils se recouvrent de vase ou de parasites, placés trop tard, ils perdent leur utilité.

Dans ce but, les inspecteurs, chefs des laboratoires régionaux de l'Office des Pêches et leurs aides, se livrent, dès que la température semble favorable, à diverses observations.

Des dragages de plancton sont faits dans les environs des gisements et des groupes de parcs, des larves d'huîtres sont dénombrées, la composition de plancton examinée.

Les températures sont relevées chaque jour, la densité moyenne de l'eau de mer est prise, les chutes de pluie sont enregistrées au pluviomètre. Enfin, on mesure, de temps à autre, le degré d'oxygénation de l'eau et son pH.

On fait connaître aussitôt les résultats des constatations aux ostréiculteurs par affichage, communications à la presse et T.S.F. Les plus pressés d'entre eux se mettent en relation téléphonique avec les laboratoires.

Enfin, les résultats sont confrontés chaque année et publiés dans la *Revue des Travaux* de l'Office des Pêches.

Le détroquage.

Le naissain recueilli, il y a avantage, pour éviter la déformation des jeunes huîtres trop serrées sur les collecteurs, à les détroquer assez tôt. Cette opération se fait au printemps suivant pour les huîtres captées en été.

Les tuiles sont amenées à terre et les jeunes huîtres sont décollées au moyen d'un couteau spécial, ce qui facilite beaucoup le chaulage des tuiles. Chaque huître emporte au talon un fragment de l'enduit calcaire.

Le naissain de plates mesure alors 2 à 3 centimètres; il en faut de 1,000 à 1,200 pour faire un kilogramme, y compris le petit support adhérent. Le naissain de Portugaise est plus gros. Là encore, les circonstances extérieures, en particulier la température de l'eau, font varier les résultats.

B. L'élevage.

L'huître détroquée est encore peu résistante et serait une proie trop facile pour les crabes et autres dévorants. D'autre part, beaucoup sont blessées, car la coque trop fragile a souvent été brisée par le couteau. On la place alors dans les caisses ostréophiles, sorte de boîtes grillagées et divisées en compartiments ou dans les parcs spéciaux, entourés de branchages ou protégés au moyen de grillages.

Plus tard, on les étale sur les parcs d'élevage. De façon générale ces parcs sont situés en pleine mer (étalages de Cancale, viviers de Marennes, parcs et plaines d'Arcachon), l'huître prospérant mieux dans des eaux agitées par des courants que dans les eaux absolument tranquilles.

Ils sont entourés de branchages ou de petites murailles de pierre sèches. L'huître y fait "sa pousse" pendant une saison au moins. Cette pousse (augmentation de la coquille) se fait plus ou moins lentement suivant le terrain. Pendant cette période, l'huître est en butte aux attaques de ses nombreux ennemis, et le déchet est souvent important malgré toutes les précautions prises.

Les parcs d'élevage ne sont pas toujours accessibles. On ne les installait jusqu'ici que sur des terrains émergeants, c'est à dire découvrant au moins à certaines marées. Depuis quelques mois, des concessions sont accordées en eaux profondes ainsi que cela se pratique en Hollande, en Angleterre et en Amérique.

Le travail des parcs en mer est facilité par l'emploi des machines à pêcher qui permettent de "lever" les mollusques sous l'eau.

De plus, même dans les meilleures conditions, la mortalité sévit sur les parcs. Les maladies des mollusques sont nombreuses.

Ennemis et maladies des huîtres.

Parmi les plus redoutables de ces ennemis, il faut citer les astéries ou étoiles de mer.

On a lutté contre les astéries au moyen de fauberts qui les capturent en s'accrochant à leurs épines, à la drague, au moyen de pompes à succion; le saupoudrage au sulfate de cuivre est très efficace, celui par la chaux vive a un effet immédiat, sur l'étoile sans gêner sensiblement les mollusques. Les corps des astéries fournissent un excellent engrais, malheureusement trop peu connu.

Un autre adversaire redoutable est le bigorneau perceur que nous retrouverons parmi les coquillages, il perce la coquille au moyen de sa radula, garnie de petites dents très dures. Ici encore, l'action est favorisée par la sécrétion d'un liquide spécial. Il faut ramasser les perceurs ou cormaillots à la main et surtout récolter leurs oeufs, qui, semblables à des grains de blé rassemblés en grappes jaunâtres sont fixés à un support solide, pierre ou coquille. Le perceur aimant grimper, on peut le capturer sur des blocs cylindriques placés à cet effet sur les parcs.

Le crabe broie facilement les jeunes coquilles entre ses pinces ou introduit sa patte dans l'huître adulte.

Il l'y laisse parfois, inconvénient relatif, car elle repousse.

On le capture au moyen de pièges spéciaux. Certains parcs, "les barrages", sont entourés de grillages, d'autres en sont complètement recouverts pour éviter l'intrusion de ces dangereux animaux. Les naissains sont placés dans des caisses grillagées et bien closes.

Les crevettes roses détruisent les petits naissains à coquille peu résistante. Les oursins rongent les pousses des jeunes huîtres en Méditerranée.

Des poissons, les tères ou pastenagues (*Trygon pastinaca*), les pagres ou les gueules pavées (*Pagrus pagrus*) broient coquilles et mollusques. On les écarte en entourant les parcs de branchages et en les garnissant de petits piquets, les "pointus".

Bien d'autres animaux sont accusés à tort ou à raison de faire des dégâts dans les parcs ou les collecteurs.

Beaucoup d'entre eux sont nuisibles en ce qu'ils occupent les collecteurs, ou étouffent les huîtres ou encore absorbent une grande partie de la nourriture (concurrence vitale), tels les anomies, les ascidies ou pissous, les balanes, les serpules, etc. ... et surtout les moules qui facilitent en outre l'envasement des parcs.

Il est aussi des plantes nuisibles; les algues qui couvrent les fonds, pourrissent sur les parcs, parfois enlèvent les huîtres, grâce à leurs flotteurs (*Colpomenia sinuosa*).

Un précieux auxiliaire est le bigorneau ou vignot (*Littorina littorina*) qui se promenant sur les huîtres, écarte la vase, et mange les algues, en particulier le limon. Les huîtres sont sujettes à maintes maladies: l'arrêt de la pousse qui fait les "huîtres boudeuses" le chambrage: formation mécanique de poches dans la nacre dont certaines sont remplies de vase ou d'un liquide à odeur nauséabonde. D'autres chambres sont causées par des vers (Polydora) qui creusent des galeries dans la coquille; la maladie du pied causée par un champignon qui vit sous la nacre, la maladie du pain d'épices produite par un éponge du genre Clione, etc.

D'autres facteurs de pertes existent:

Le douçain, excès d'eau douce qui gonfle le foie de l'huître et la tue rapidement.

Le froid qui l'empêche de s'alimenter.

La chaleur qui tue les huîtres non recouvertes d'eau, etc....

A ce propos, car la chaleur et la longueur des transports peuvent seules être mises en cause, je dois noter l'inanité de la légende des mois sans R.; les huîtres élevées et dressées pour l'expédition sont aussi bonnes en été qu'en hiver. Seules sont, non pas nocives, mais peu appétissantes, les huîtres "en lait", c'est à dire occupée à se reproduire. C'est à l'ostréiculteur à choisir ses huîtres en cette période; pour le reste, la fraicheur suffit. Une huître fatiguée ne joint plus des coquilles, elle ne renferme plus d'eau. Une huître fraiche, bien pleine, bien emballée voyage facilement et arrive en bon état au consommateur.

C. L'affinage ou engraissement.

A trois ans, une huître est généralement de belle taille, mais elle n'est pas grasse. Les huîtres engraissent peu là ou elles ont bien poussé; il faut donc en achever l'élevage dans des parcs spéciaux dits parcs d'engraissement.

Cet engraissement est, à vrai dire, une hypertrophie du foie qui se surcharge d'une matière hydrocarbonée, le glycogène, aliment de réserve.

Certains fonds ostréicoles se prêtent spécialement bien à cette dernière phase de la culture de l'huître; voyons successivement quels sont les procédés employés dans ces centres:

Dans le Belon, les huîtres sont étalées sur des parcs situés dans la rivière même. Il est vrai que celle-ci est plutôt comme beaucoup de rivières Bretonnes, une échancrure, un fjord et qu'en temps normal son eau est composée d'un mélange d'eau douce et d'eau de mer où la seconde prédomine de beaucoup.

Il a fallu créer ces parcs de toutes pièces; presque partout les abords du chenal, à quoi se réduit la rivière à marée basse, présentaient des bancs de vase et les huîtres y disparaissaient. Les vases furent enlevées sur une épaisseur variable, mais atteignant quelquefois un mètre; le sol fut macadamisé, durci par l'adjonction d'une couche de sable ou de gravier d'autant plus épaisse que la vase y était plus molle. Le sable s'incorpore à la vase et la transforme en un terrain solide. Il faut prendre garde que le niveau final soit au moins le même que le niveau primitif, sinon l'envasement se reproduirait.

Dans la Pénerf, le Morbihan et au Croisic, les huîtres sont mises dans des caisses à fond grillagé soutenues par des piquets à 0.35 m. ou 0.50 m. du fond. Les huîtres y sont remuées pendant la période de pousse (Avril à Septembre) pour éviter le "maillage" et "la soudure".

Dans la région de Marennes, l'engraissement se fait dans les claires. Ce sont des bassins creusés dans les terres, bien souvent d'anciens marais salants désaffectés.

Toute la région de la Seudre, sur une largeur de 5 à 6 kilomètres et sur plus de 20 kilomètres de longueur, est divisée en prises qu'alimentent des chenaux subdivisés en ruissons. Les claires sont séparées les unes des autres par des levées de terre au bas desquelles sont creusés des fossés destinés à recevoir la vase amenée par le flot et à servir à l'écoulement de l'eau lors de la mise à sec.

L'eau de mer est admise dans la claire par des vannes ou par des coupures dites "dérases", pratiquées dans les levées de terre, ou encore par submersion.

Cette eau de mer y reste plus ou moins longtemps, selon la situation de la claire par rapport au niveau des marées; elle se clarifie et la vase en tombant sur le fond amène aux huîtres une nourriture abondante. Sa coquille grandit plus ou moins, l'huître y durcit et engraisse rapidement.

Les claires demandent beaucoup d'entretion. Chaque année, généralement au mois de Mars, il faut procéder au parage. Vidées de leur eau, la couche

superficielle de vase enlevée, on les laisse se désécher au soleil jusqu'à ce que leur sol se fendille. Une petite quantité d'eau y est admise ensuite, la croute s'y délaye et un dépôt uniforme se fait sur la claire, c'est "l'humeur". La claire est prête alors à recevoir les huîtres. Tous les quatre ou cinq ans, elle doit être recreusée (piquée) en raison de l'exhaussement du fond.

C'est dans ces claires que se fait le "verdissement" de l'huître:

Ce complément de l'élevage de l'huître est pratiqué dans la région de Marennes; à Oléron, dans l'île de Ré, à Fouras et dans certaines régions de Bretagne.

Le verdissement est dû à la fixation dans les branchies de l'huître d'une substance colorée, un pigment (la marennine) produit par une diatomée, la navicule bleue (*Navicula ostrearia*).

Cette pigmentation n'est pas un caractère permanent, mais un caractère acquis sous l'influence des conditions de milieu très variées.

L'huître absorbe les diatomées bleues et leur pigment véhiculé par le milieu intérieur se fixe notamment au niveau des branchies qu'il colore. Cette absorption du pigment se fait non seulement par le tube digestif, mais encore par la surface extérieure du mollusque.

La navicule abonde à certaines époques de l'année dans les claires riveraines de la Seudre; l'apparition et le développement de la verdeur sont très capricieux. Il n'est pas possible de prévoir exactement quelle claire verdira ou ne verdira pas; assez fréquemment dans une rangée de claires, quelques-unes seulement verdissent; d'autres fois, une claire "boude" au milieu de toutes les autres qui ont verdi. La verdeur disparait lors des grandes pluies; elle cesse quand l'eau est trop agitée, elle cesse même quelquefois sans raison apparente. Les apports de sels minéraux (engrais) semblent la favoriser.

Dans une claire verte et bien à point, l'huître verdit en quelques jours et sa valeur marchande est très augmentée.

La renommée des huîtres vertes est méritée, par la nourriture de choix qu'elle absorbe dans les claires, l'huître en verdissant prend une saveur spéciale très appréciée des gourmets.

D. L'expédition.

L'huître, mise au point, doit être dégorgée, trompée, emballée et expédiée à la consommation.

Ces dernières opérations se font à l'établissement d'expédition.

L'emplacement de cet établissement doit être choisi avec soin; il doit en effet, pouvoir s'alimenter en eau pure, se trouver à proximité des parcs d'élevage d'une part, des moyens de transport de l'autre.

Tout établissement comporte essentiellement des bassins d'expédition qui, jadis simples dépôts transitoires, simples réserves d'huîtres, sont devenus en outre des bassins d'épuration où l'huître arrivant des claires, parcs ou viviers, se dépouille du sable et de la vase que peut renfermer sa coquille, dégorge ses impuretés pour se présenter dans un état de propreté parfaite, remplie d'une eau limpide et savoureuse.

Ils sont établis sur le rivage de la mer ou même à l'intérieur des terres où ils sont alors desservis par des canaux alimentés au moyen de pompes. Les uns sont submergés à toutes les marées, d'autres ne le sont qu'aux plus fortes ou sont complètement insubmersibles.

Les bassins submergés sont établis sur le sol; ou creusés dans celùi-ci. Ils doivent retenir l'eau et sont pour celà entièrement clôturés. Cette clôture est en bois ou en maçonnerie.

Le fond est d'argile, de gravier ou de maçonnerie.

Pour les parois et pour le fond, nous donnons la préférence à la maçonnerie plus solide et plus facile à tenir propre.

Si les huîtres reposent sur le sol, celui-ci doit pouvoir être nettoyé fréquemment et à fond. Il doit donc être uni et légèrement incliné vers l'orifice de vidage.

Dans les bassins à fond d'argile, les huîtres ne peuvent pas être déposées à même le sol. On les dispose donc dans des casiers constitués par des cadres en bois goudronné et un fond de grillage métallique. Ces casiers sont eux-mêmes placés sur des solives à quelque distance du sol. La vase rejetée par les huîtres tombe sur le fond, qui s'exhausse peu à peu et doit être refait à chaque campagne. C'est le système encore pratiqué à l'heure actuelle dans la plupart des établissements Arcachonnais submergés ou non. Les bassins doivent pouvoir se vider complètement pour permettre et le nettoyage et le trompage. Ils sont munis dans ce but d'une vanne ou d'une buse de vidage. Les dimensions de ces bassins sont très variables, il y en a de quelques mètres carrés, il y en a de très grands. Leur profondeur est généralement telle qu'on puisse y tenir au moins 40 centimètres d'eau.

Les bassins submergés doivent être protégés contre l'accès des premières eaux du flot et les dernières du jusant qui sont les plus suspectes. Des parois, plus ou moins élevées suivant le cas, remplissent cet office ou, si l'alimentation ne se fait pas simplement par submersion, la vanne ou la buse permettant l'accès de l'eau dans le bassin sont élevées au-dessus du sol, de manière à éviter l'entrée des eaux souillées. Elles ne sont ouvertes qu'un certain temps après le début du flot, pour écarter l'eau de surface qui est fortement mêlée d'eau douce chargée des souillures du rivage.

Parfois l'alimentation se fait par siphonage.

Sur les côtes de la région de La Rochelle on se sert d'arches ou de cages-dégorgeoirs. Ce sont des caisses à claire-voie fermées par un couvercle cadenassé et montées sur des pieds de 1·25 m. de hauteur. Elles ont jusqu'à 4 mètres de long, 1·30 m. de large et 0·40 m. de haut. Les coquillages qu'on y dépose sont immergés à chaque marée.

Les cages que l'on trouve dans le même quartier consistent en un plancher à claire-voie, établi à 30 ou 40 centimètres au-dessus du sol et entouré sur trois côtés par une paroi verticale, également à claire-

voie, de 0·40 m. environ de hauteur. Pendant le mauvais temps, on recouvre les huîtres d'un grillage métallique solidement fixé à la paroi. Une cage de ce genre, mesurant 6 à 7 mètres de long et 1·10 m. à 1·20 m. de large, peut contenir 20,000 à 30,000 huîtres suivant leur grosseur.

Ces installations rudimentaires ne peuvent convenir qu'à de petites exploitations.

Les établissements non submergés et situés sur la côte prennent leur eau, soit à l'aide d'une vanne ou d'une buse lorsque la marée les atteint, soit s'il y a lieu, à l'aide d'un conduit et d'une pompe actionnée par un moteur. L'eau est captée assez loin du rivage. Une crépine, surélevée au-dessus de la vase, arrête les algues et autres corps susceptibles de boucher le tuyau.

Plus loin de la mer, on a recours à des réserves d'eau. Remplies aux marées favorables, elles conservent la provision d'eau nécessaire au service des bassins et la fournissent, claire, décantée, donc débarrassée des particules de vase et des germes vivants (parfois nuisibles) qui s'y accrochent. A la décantation, se joint l'influence purifiante des rayons de soleil, riches en radiations ultra-violettes et l'eau qui y a séjournée de 5 à 6 jours au minimum sera pratiquement pure (si toutefois elle n'était pas, à l'origine, fortement souillée). Ces réserves ne servent jamais de lavoir à huîtres, ni de dépôts d'huîtres, car toute agitation de l'eau remet en suspension les parcelles solides séparées par la décantation.

L'introduction de l'eau de la réserve dans le bassin est toujours faite avec précaution doucement pour ne pas troubler l'eau, laquelle est prise dans une zone bien clarifiée, c'est-à-dire suffisamment au-dessus du fond de la réserve.

On adjoint aux dégorgeoirs un ou plusieurs lavoirs, dans lesquels la coquille de l'huître sera finalement débarassée de la vase et des parasites qui la souillent.

Un nettoyage superficiel se fait à la lance ou à la pelle avant le dégorgement; le lavoir sert surtout au dernier lavage avant l'expédition; on y secoue vigoureusement les huîtres dans de petits paniers; au besoin, on les brosse.

Dans certains établissements de la Seudre, des appareils laveurs mécaniques à grand rendement sont employés; les huîtres placées sur un tapis roulant sont amenées sous un courant d'eau et déversées sur les tables d'expédition à la cadence de 20 à 25,000 à l'heure.

Lavoirs et dégorgeoirs sont indépendants les uns des autres. Les prises d'eau et bondes de vidage sont disposées de façon à ce qu'on puisse remplir, vider, nettoyer isolément chacun de ces bassins.

Ils sont construits de préférence en maçonnerie, briques, pierres cimentées ou ciment. Le nettoyage, qui doit être fréquent, et fait à fond, en est ainsi très facilité. Leurs rebords surélevés ou doublés de caniveaux, de façon à éviter l'accès des eaux sales et de l'eau de pluie qui, lorsqu'elle tombe, se souille rapidement en ruisselant sur le sol, enlevant la boue amenée par les chaussures, les déjections d'animaux, etc.

A proximité des dégorgeoirs sont construits les bâtiments destinés au triage des huîtres, à leur emballage, au groupement des colis pour l'expédition; ce sont les magasins ou cabanes. Les manutentions doivent s'y exécuter commodément et, de plus, toutes les dispositions doivent être prises pour que les huîtres ne soient pas exposées à souillure.

Ce sont les locaux d'emballage, le magasin à paniers, à paille ou à fougère, les cabinets d'aisance et, s'il y a lieu, l'écurie ou le garage. L'espace compris entre les bassins et les constructions est cimenté.

Le sol du magasin est planchéié, cimenté, les water-closets et l'écurie cimentés; les premiers sont établis sur une fosse étanche ou pourvus d'une tinette métallique, la seconde d'une fosse à purin.

Les matériaux d'emballage, paille, fougère, algues, sont rassemblés dans un local spécial ou dans un casier à claire-voie aménagé dans un angle du magasin.

L'ensemble de l'établissement est clôturé, ne fut-ce que par un simple grillage qui le met à l'abri de toute incursion indésirable (animaux domestiques, volailles, etc. ...), et protégé contre les écoulements d'eau.

E. Les établissements de la côte Méditerranéenne.

On peut les diviser en deux catégories.

Les uns sont de simples dépôts ou des établissements de relais ou de retrempage. Ils sont mixtes, c'est-à-dire qu'ils sont destinés à entreposer avec les huîtres, les moules et les coquillages qui sont très appréciés dans cette région.

Les autres sont des établissements d'élevage; dans les premiers, les produits placés dans des paniers sont suspendus au moyen de cordes accrochées aux bâtis. Ceux-ci sont composés de grands poteaux en fer ou en bois enfoncés dans le sol et soutenant des charpentes. Des passerelles facilitent la manoeuvre. Tels sont les établissements de Port-Vendres et Pomègues.

D'autres sont de solides constructions en maçonnerie dans le haut desquelles se trouve un filtre à sable, alimenté par un réservoir que remplit chaque jour une pompe. L'eau filtrée tombe continuellement dans les bassins où sont entreposés les coquillages.

Les établissements d'élevage sont installés sur la côte nord-ouest de l'Etang de Thau: des rails sont enfoncés verticalement dans le sol sous-marin de façon à émerger de 1·20 m. environ. Ils sont reliés par des plateaux en bois. Ces plateaux sont chevauchés par des chevrons ou rondins auxquels sont suspendues des barres de 1·60 m. à 2 m. en bois très dense et imputrescible en "okoumé" où sur les quatre faces de ces barres, que l'on nomme "collecteurs", sont creusés des trous. Une pointe est fichée dans chaque trou, laissant émerger la tête. Chacun reçoit une pastille de ciment à laquelle est fixée une huître.

Ces huîtres qui proviennent de Bretagne ou d'Arcachon poussent rapidement, puis se corsent. Elles gagnent en moyenne une saison sur les côtes ouest.

Le déchet est d'un tiers environ. Les ennemis les plus dangereux sont les oursins qui rongent la dentelle ou pousse, les commensaux qui étouffent presque les huîtres et absorbent leur nourriture, enfin certains poissons qui les détruisent.

Les établissements d'expédition sont installés à terre, à proximité immédiate des parcs, éloignés de toute cause de pollution. Il s'est formé là de véritables cités ostréicoles.

Le nombre des parcs s'est accru ces dernières années dans des proportions considérables et risque d'excéder les possibilités d'alimentation. Il faut créer entre eux de larges voies d'accès et réglementer leur accroissement.

III. Vue d'Ensemble.

Parcs de captage, d'élevage, d'engraissement et établissements d'expédition sont très inégalement répartis sur les côtes Françaises.

La région du nord-ouest ne compte que des petits groupes d'établissements ou des établissements isolés, en tout 10 avec 45 parcs couvrant 22 hectares.

La Bretagne, région de production d'huîtres plates, a plusieurs centres d'élevage et trois centres d'engraissement; au total 180 établissements et 4,000 parcs (1,850 hectares).

Le centre-ouest, région de production de Portugaises, possède 120 établissements d'importance très inégale et 8,400 parcs (800 hectares).

La région de Marennes-Oléron où se fait l'élevage des deux espèces compte 670 établissements d'expédition et 24,000 parcs ou groupes de claires (3,500 hectares).

Parmi ces parcs, plus de 20,000 (2,300 hectares) s'échelonnent sur les vasières découvertes par la mer entre le continent et l'île d'Oléron.

D'autres se trouvent sur les rives de la Seudre elle-même, cours d'eau qui simple ruisseau d'abord s'épanouit en un estuaire de 16 kilomètres de longueur sur 500 à 1,500 mètres de largeur. A droite et à gauche de l'estuaire aboutissent de nombreux affluents appelés chenaux, qui reçoivent eux-mêmes des ruissons. Ceux-ci découpent en centaines de compartiments, les prises, les terrains marécageux qui s'étendent des deux côtés de la Seudre.

Les concessions au nombre de 3,000 environ (1,300 hectares) sont divisées elles-mêmes en claires, dont on a pu évaluer le nombre à trente mille. On en trouve d'autres encore le long de la côte de Marennes et près du rivage est de l'île d'Oléron.

Les établissements sont groupés, soit sur les bords de la mer, soit formant de véritables cités ostréicoles, sur les bords des chenaux. Il faut citer l'agglomération de la Tremblade (la Grève et le Route-Neuve) qui, sur moins de 2 km^2., compte plus de 100 établissements d'expédition desservis par une ligne de chemin de fer à voie normale, un canal et la rivière.

La région du sud-ouest possède 200 établissements d'expédition et 5,800 parcs (1,300 hectares) presque tous groupés dans le Bassin d'Arcachon. Là, on capte, élève et expédie les deux espèces d'huîtres.

Enfin la région du sud-est a 40 établissements d'expédition avec environ 300 parcs, réserves ou dépôts occupant en tout un peu plus de 60 hectares.

Au total, plus de 1,200 établissements d'expédition, plus de 42,000 concessions couvrant 8,000 hectares. Les gisements naturels classés en occupent 3 à 4 fois autant.

Cet ensemble expédie annuellement à la consommation, en paniers, caissettes ou barils, tous munis de l'étiquette de salubrité réglementaire, plus de 60,000 tonnes d'huîtres dont la valeur est très variable suivant qu'il s'agit de Portugaises de pêche, de viviers, de claires et d'huîtres plates ordinaires ou de premier choix.

Référence.

L. Lambert. "Les Coquillages Comestibles (Huîtres, Moules, Coquillages variés)." Collection "Que sais-je?", 1° Partie, Presses Universitaires de France, Paris, 1950.

5.

Fluctuations in the Stock of Oyster (*Ostrea edulis*) in the Limfjord in Recent Time.

By

R. Spärck

The oyster stock in the Limfjord in Denmark is a comparatively young population. Until 1825 the western part of the Limfjord, which to-day harbours the oyster stock, contained brackish water of a salinity of 2—3‰ which completely excluded the presence of oysters.

In the year 1825 the North Sea broke through the isthmus which separated the western Limfjord from the sea thus totally changing the salinity and other natural conditions of this water. About 1850 natural oyster beds were found at various places in the western Limfjord, so that the natural oyster populations are not more than about a hundred years old. Within this period this stock has been subject to pronounced changes in number (Table I), with an increasing stock in the years 1860—70 and 1900—14 and decreasing stocks about 1880—90 and 1914—32 (for further details cf. the papers by Petersen of 1908, Spärck 1925, 1935).

As pointed out in my paper of 1935 it must be considered probable that a new period with an increasing stock of oyster in the Limfjord could be anticipated inspite of the fact that the stock in the period from 1914 to 1932 had been subject to a very considerable decrease in number. In 1932 I estimate that the number of oysters on natural beds had dwindled to about 10% of the number in 1914, which at that time was presumably about 150 mill.

The depletion of the stock of oysters on natural beds in the Limfjord in the above-mentioned period was not evenly distributed; in large parts of the fjord the decrease was even greater than 90 per cent. and it appears that in a few restricted areas the decrease was much less. It should be pointed out that in the period from 1925 to 1937 there was no oyster fishing at all on the natural beds in the Limfjord, so that the stock decreased only on account of natural conditions. There can hardly be any doubt that the fluctuations are mainly governed by the summer temperature since the periods of increase coincide with periods of warm summers (mean temperature in July of the surface water of the Limfjord about 18° C. or more) while periods of decrease coincide with

Table I. Production of Native Oysters in the Limfjord in the period 1852/1949 (in thousands).

1852/53	about 30	1902/03	1025
1855/56	about 86	1903/04	1092
1860/61	about 150	1904/05	1069
1865/66	1147	1905/06	1239
1866/67	1207	1906/10	no statistics available, the production about 1.000 a year
1867/68	1727		
1868/69	3868		
1869/70	4621		
1870/71	5343	1910/11	3430
1871/72	7519	1911/12	3752
1872/73	7512	1912/13	3980
1873/74	7365	1913/14	3925
1874/75	5551	1914/15	3956
1875/76	5933	1915/16	5622
1876/77	5522	1916/17	4739
1877/78	3556	1917/18	2465
1878/79	2629	1918/19	3977
1879/80	2876	1919/20	4722
1880/81	1480	1920/21	4172
1881/82	2076	1921/22	3373
1882/83	1760	1922/23	2526
1883/84	1320	1923/24	1142
1884/85	947	1924/25	490
1885/86	(922)	1925/37	no fishing on natural beds
1886/90	no fishing		
1890/91	587	1937/38	11
1891/92	775	1938/39	8
1892/93	872	1939/40	24
1893/94	765	1940/41	8
1894/95	891	1941/42	23
1895/96	1007	1942/43	56
1896/97	1054	1943/44	46
1897/98	1165	1944/45	19
1898/99	1088	1945/46	274
1899/1900	994	1946/47	162
1900/01	1010	1947/48	890
1901/02	1133	1948/49	993

Table II. Number of Native Oyster Spat collected in the Limfjord in the period 1910/49 (in thousands).

1910/11	235	1925/37	no fishing on natural beds and no spatfall of any importance
1911/12	392		
1912/13	1273		
1913/14	3240		
1914/15	2632	1937/38	4
1915/16	3462	1938/39	98
1916/17	2498	1939/40	134
1917/18	586	1940/41	14
1918/19	577	1941/42	9
1919/20	1410	1942/43	22
1920/21	1408	1943/44	11
1921/22	1194	1944/45	34
1922/23	394	1945/46	4173
1923/24	149	1946/47	923
1924/25	58	1947/48	1366
		1948/49	1629

periods of cold summers (mean temperature in July of surface water in the Limfjord 17° C. or less).

The prediction in 1935 that a turning point in the decrease in the number of natural oysters in the Limfjord had been reached has proved true. As it will be seen from Table II oyster spat occurred again in 1932 in considerable numbers in certain restricted areas, and this was repeated in several of the following years, notably in 1939, 1942 and 1943. Finally, in 1945 the production of spat was so large that more than 4 million spat were taken in the winter of 1945—46 on natural beds in that part of the Limfjord which is situated between Oddesund in the west and Nykøbing in the north-east, an area of about 200 sq. km., and transferred to the artificial beds in Nissum Bredning. This spat originated mainly from the warm summers of 1943 and more particularly of 1945. In the winter of 1947—48 this spat had grown up so that a considerable oyster fishery could be based on it. From the natural beds, mainly situated between Nygårdshage and Kås in the Venø Bredning, 993,387 oysters were dredged in 1948—49. If we look at the age composition of the stock on the natural beds in the Limfjord in 1948—49 compared, e. g., to the composition of the majority of the beds in 1934 or 1937 there is a striking difference. In 1948—49 only a few per cent. were older than 5—6 years, while in 1934 and 1937 the majority were of an age of about 8—12 years.

This very considerable increase of the oyster stock on natural beds mentioned above has been restricted to the Venø Bredning, the waters round Jegindø, the Lysen Bredning, Harrevig and to Klosterbugten near Nykøbing. In great parts of the fjord, primarily the large Nissum Bredning and the Løgstør and Livø Bredning, no increase at all has occurred as will appear from Table III. In these parts of the fjord it is only possible to dredge two to three oysters in one 15-minute haul, just as was the case ten years ago. A conspicuous change, however, has taken place, since young oysters of 5—6 years, though in small numbers, characterize the very scarce stock in these parts of the fjord. In the northern part of Salling Sund and in the waters south of the island of Fur a certain increase has taken place in the last few years as will appear from Table IV, which gives the results of some dredgings in the summer of 1949.

It is very striking that the increase of the oyster stock has taken place in parts of the fjord far from where there are large artificial beds to which millions of Dutch, French and Norwegian spat have been transplanted during the last 25 years. It looks as if this enormous addition of oyster to the Limfjord on the artificial beds has been without any importance to the increase which has occurred on natural beds in the last 10—15 years. This is further confirmed by the fact that the increase on the natural beds started in that locality—Nygårdshage in Venø Bugt—where the number left of the old natural stock was relatively the greatest.

If we compare the increase in the natural oyster stock in the Limfjord in the last 10—15 years with the particulars available of the original invasion of oyster to the Limfjord about 100 years ago, the resemblance is remarkable. In the years about 1850 the first oysters were taken in the Limfjord in small inlets and bays in the more protected parts of the fjord (Lemvig, Lysen, Harrevig etc.) just the same parts where the new increase in the last few years started. It seems as if such localities are to be regarded as foci from which the stock spreads to the other parts of the fjord in periods with specially favourable conditions to the oyster.

On account of the great fecundity of the oyster one has been inclined to believe that in years with favourable conditions a sudden and an enormous increase of the stock would take place. When we look at the fluctuations of the natural oyster stock in the Limfjord in recent time it is quite clear that the fluctuations, though great, are at the same time slow. When the natural stock has been depleted to a high degree, as in the years about 1885 and 1930, the increase does not set in suddenly in a single favourable year. A long series of favourable years is necessary. If a series of unfavourable years occurs the natural stock slowly decreases, at first in the less favourable localities, and eventually becomes restricted to a few particularly favourable localities in some inlets. In favourable years the stock increases slowly, starting from these localities, and if a number of favourable

Table III. Results of Oyster Dredgings in Livø Bredning in the summer of 1949 (each haul 15 minutes).

Locality	Number of oysters
Færker Vig	0
Grønør Odde	0
Livø Tap	0
North-east of Fur	1
North of Fur	0
North of Fur	0
North-west of Fur	1
West of Fur	1

Table IV. Results of Oyster Dredgings in the Limfjord south of Fur in the summer of 1949 (each haul 15 minutes).

Locality	Number of oysters	Year-Classes						
		1937	1939	1940	1943	1945	1947	1948
S.W. of Fur ...	21	2	4	1	—	5	7	2
Trehuse	25[1])	—	2	—	3	6	6	8
The Sound (Fur/Salling)...	14	—	—	—	3	—	8	3

[1]) + many from 1949.

years occurs the population spreads to less favourable localities. KORRINGA quite recently (1946) set forth the view that it is impossible to revive an extinct oyster population by transplanting mother oysters from another area. Our experience from the Limfjord to a certain degree confirms this view, since the increase of the natural stock in the last fifteen years evidently has occurred exclusively from the small remnants of the natural oyster population without any influence from the large stock of transplanted oysters. On the other hand, our experience from the Limfjord shows that even if a natural oyster population has decreased to one or two oysters per 100 sq. m. the possibility exists that the stock may, in the course of some ten years, again attain such a density that the fishery will be remunerative.

1914, which until 1932 was the last year with a spatfall of any importance in the Limfjord, shows an augmentation of about 100 per cent., i. e., for each adult oyster one grown-up spat settled. Considering the great fecundity of the oyster this must appear striking, but the experience from later years confirms this view. Even in the most favourable years the loss of fry is so enormous that only one per million is supposed to survive.

The fluctuations in the natural oyster stock thus differ to some extent from the fluctuations in the stock of food fishes. The fecundity of the food fishes is also very great, but in favourable years the survival of fish larvae seems to be much greater than that of oyster larvae. In favourable years the fishery is based on one or a few abundant year-classes, while the oyster fishery on natural beds in favourable years is based not on one or two year-classes but on a series of year-classes which indicate a series of favourable years to come, if spawning conditions are good.

The fluctuations of the native oyster stock in the Limfjord as mentioned above are due to fluctuations in the spatfall which again is governed mainly by weather conditions. To a smaller extent fluctuations are influenced by severe winters which in the years 1939—42 completely depleted the stock of relaid French oysters, and in some degree the Norwegian oysters also, but the natives only to a small extent. In certain years also a summer mortality, although small, has been detected, but only among the relaid oysters, not on natural beds. Imported pests which in other areas in western Europe (Holland, England) seem to be detrimental, are of no importance in the Limfjord. The American whelk tingle, *Urosalpinx cinera*, and the Australian barnacle, *Elminius modestus*, have not yet been found in the Limfjord, whereas the slipper limpet, *Crepidula fornicata*, occurred in the Limfjord for the first time about 1932, presumably introduced together with Dutch spat. The latter has now spread throughout the Limfjord and further to the north-western Kattegat, but occurs in so small numbers that until now it has been of no importance. The shell disease which is so prevalent in Holland has never appeared in the Limfjord among natives, although Dutch oyster spat was imported in large quantities in the period from 1922 to 1931. The so-called disease which was present in western Europe in the years 1920—21 was not detected in the Limfjord, either on the natural beds or among relaid oysters. Thus it is obvious that fluctuations in the native oyster stock in the Limfjord are neither due to the influence of the fishery, nor to pests or diseases, but only to weather conditions.

Our experiences in the Limfjord exactly confirm the results obtained by COLE and KNIGHT JONES on the gregariousness of the oyster spat, since restocking only took place to any considerable degree in places where the density of the residual native oysters was fairly great, and since the consequent restocking slowly spread from these places. In contradistinction to the experience on English oyster grounds, restocking in the Limfjord was due exclusively to the native stocks, while the imported and relaid stock seems to have been of very little importance, if any at all. This difference may be due to the fact that the oysters in the Limfjord live under less favourable conditions than in British waters, nearer to the limit of distribution of the species. This seems to indicate that the native stock of the Limfjord, though the population is not more than a hundred years old, has developed into a local race, which has become adapted to the particular conditions near the limits of the species. This seems to be the cause of the great difficulties experienced in restocking natural oyster stocks in waters such as those on the west coasts of Sweden and Norway. Further investigations of the local races of oysters and the ecology of these races, will no doubt be of great importance to the oyster industry.

6.

Aspects of the Setting Behaviour of Larvae of *Ostrea edulis* on Essex Oyster Beds.

By

E. W. Knight-Jones

Introduction.

The choice of a suitable site for attachment by oyster larvae at the end of the planktonic stage is very important for survival. Their preferences are also of economic interest because on settlement the oyster becomes amenable to handling and an article of property, real or potential. Most processes of cultivation of oyster beds aim primarily at increasing the spatfall upon them. In Essex creeks tidal currents are sufficiently strong to sweep planktonic larvae several miles in a few hours, so the searching phase which concludes the planktonic life of *Ostrea edulis* probably enables the larvae to visit a variety of situations in widely separated localities. Studies of their settlement behaviour rank highly amongst the ways in which research may be expected to help in increasing productivity.

Such studies have been carried out in large concrete tanks at the Fisheries Experiment Station, Conway, by Cole and Knight-Jones (1939, 1949) and in the Oosterschelde by Korringa (1941). These accounts also review work on other species of oysters in U.S.A., Canada and elsewhere.

Comparison between Attachment to Upper and Lower Surfaces.

Attachment to plane surfaces has been investigated by several previous workers, both as an essential preliminary in an analysis of larval behaviour and as a guide to the best use of artificial collectors. All agree that lower surfaces are much more favourable for attachment than vertical surfaces, but conflicting results have been obtained regarding relative suitability for attachment of upper surfaces. The bulk of the evidence points to upper surfaces being generally less favoured than lower surfaces but under certain conditions this behaviour is reversed (see Cole and Knight Jones, 1949) and Korringa (1941) found that *O. edulis* in the Oosterschelde favoured the upper rather than the lower surfaces of his test plates. These were held one above the other in concrete containers and must have been subject to some degree of turbulence.

In the Burnham-on-Crouch district during 1947 and 1948 the routine method of following the course of the spatfall was to expose smoothed slates for weekly periods throughout the breeding season. The slates were held horizontally 5 cm. above the surface of concrete slabs, which were placed on the bottom at a depth of a few metres at low water. Each slate was held only by four thin upright bolts, so there was little to restrict the movement of water over its surfaces or to cause turbulence.

After a week's immersion each slate was replaced by a clean one and all sessile organisms on each side were counted. All spat which settled on the upper and lower surfaces of these slates during 1947 and 1948 are recorded in Table 1 A and B. The data are presented in two separate parts because of the possibility that heavy settlements of the barnacle, *Elminius modestus*, might have affected the behaviour of the setting oyster larvae. All slates which bore few barnacles (less than 0·5 per cm.^{2} on both surfaces) are grouped in Table 1 A, the remainder (more than 1 barnacle per cm.^{2} on one or both surfaces) in Table 1 B. The settlement of other organisms was negligible compared with that of *Elminius modestus*.

Table 1 A shows that setting of oyster larvae was consistently heavier on the lower surfaces of the slates than on the upper surfaces. In the aggregate over nine times as many settled on the lower surfaces as on the upper surfaces. The upper surfaces collected some silt but this did not form permanent or continuous layers during these brief periods of exposure and it is unlikely that the sparseness of setting on the upper surfaces was due to mere mechanical obstruction.

Table 1 B also shows a considerable balance in favour of the lower surfaces. On most slates there was the usual ratio, unaffected by heavy settlements of barnacles on both sides, but on some there was little difference between the two sides. Since Table 1 A indicates a consistent preference for lower surfaces,

Table 1. Comparison between Spatfall on upper and lower Surfaces of horizontal Slates exposed for periods of a week.

A. Critical results (settlement of other organisms less than 0.5 per cm.²).

Date – 1948	Locality	Upper	Lower	Barnacles per 212 cm.². Upper : Lower
24. June—1. July	Paglesham Pool	1	2	7:58
24. June—1. July	Roach Mud	nil	1	nil
29. July—5. Aug.	Broadrakes	nil	7	35:45
29. July—5. Aug.	Pag. Pool	2	7	nil
29. July—5. Aug.	R. Mud	6	85	96:92
27. July—6. Aug.	Althorne Creek	2	14	1:nil
6.—10. Aug. ...	Fambridge	1	3	37:76
6.—10. Aug. ...	Althorne Creek	nil	1	nil
5.—12. Aug. ...	Broadrakes	nil	4	24:42
5.—12. Aug. ...	R. Mud	4	19	93:24
9.—14. Aug. ...	Quay loading	nil	1	3:7
10.—17. Aug. ...	Fambridge	nil	3	5:3
10.—17. Aug. ...	Purleigh Shore	nil	10	nil:2
	Totals ...	16	157	

Totals of A and B:
Upper 96, Lower 381.

B. Results which might have been influenced by settlement of barnacles of more than 1 per cm.².

Date – 1947	Locality	Upper	Lower	Barnacles per 212 cm.². Upper : Lower
29. July—2. Aug.	Shop Laying	1	4	1,115:723
Date – 1948				
22.—30. June ...	Althorne Creek	1	nil	36:1,497
22.—30. June ...	Creeksea	1	1	746:928
24. June—1. July	Bush Shore	nil	1	8,340:5,600
22.—29. July ...	Shop Laying	nil	1	1,740:899
22.—29. July ...	Roach Mud	nil	6	259:152
22.—29. July ...	Roach Mud	1	3	357:8
22.—29. July ...	Bush Shore	1	1	4,210:3,580
29. July—5. Aug.	Shop Laying	14	50	1,029:349
29. July—5. Aug.	Bush Shore	4	3	7,900:8,000
27. July—6. Aug.	Fambridge	4	5	5,800:5,240
7. July—6. Aug.	Creeksea	44	138	880:1,250
6.—10. Aug. ...	Purleigh Shore	1	nil	35:955
6.—10. Aug. ...	Creeksea	5	10	271:76
5.—14. Aug. ...	Bush Shore	3	1	900:247
	Totals ...	80	224	

the inconsistencies in Table 1 B suggest that heavy settlements of other organisms may affect the setting behaviour of oyster larvae.

Slates which were left undisturbed for more than a few weeks developed in most localities thick growths of filamentous diatoms over the whole of the upper surface. Silt settled thickly and formed a continuous sheet of mud, protected by the filaments from the scour of tidal currents. A few live spat were found beneath this—presumably survivors of spat which had settled during the first few weeks of exposure. Such muddy algal layers were thickest on slates from Tollesbury Fleet, River Blackwater, where the water is clear and tidal currents slight. The numbers of spat recorded on these slates during 1948 are given in Table 2 A. The great differences between upper and lower surfaces in favour of the latter are striking. Of the slates exposed throughout the season in the Rivers Crouch and Roach (Table 2 B) only those from Althorne Creek and Shop Laying were comparatively free from algae and mud and only that from Althorne Creek bore more spat on its upper than on its lower surface (perhaps the vast preponderance of barnacles on its lower surface contributed to this). It appears that upper surfaces are unfavourable not only for attachment but also for subsequent survival, owing to the silting which follows the development of filamentous algae. This is likely to vary in different localities, however, and in some it may be less important than competition with sessile animals. *Elminius modestus* is a serious competitor of young spat in Essex. *Membranipora lacroixi* and *Ascidiella aspersa*

Table 2. Spatfall on upper and lower Surfaces of Slates exposed for more than two months.

A. Tollesbury Fleet, R. Blackwater.

Date	Locality	Oyster Spat		Other Organisms:—Upper : Lower						
		Upper	Lower	*E. modestus*	*B. improvisus*	*Membranipora*	*A. aspersa*	*A. conchilega*	*Ciona*	*Botrylloides*
23 June—11 Oct.	S. Channel	4	14	18:nil	1:1	4:12	nil	1:1	nil:10	19:nil
13 July—11 Oct.	S. Channel	nil	55	1:8	1:1	25:25	nil:14	nil:49	nil:7	nil:5
13 July—11 Oct.	N. Channel	nil	71	35:76	nil	nil:5	nil:8	nil:17	nil:33	nil:3
13 July—11 Oct.	N. Channel	nil	105	1:5	nil:2	nil:3	nil:5	nil	nil:6	nil:4
		4	245							

B. Rivers Crouch and Roach.

Date	Locality	Spat		*E. modestus*	*B. improvisus*	*Membranipora*
		Upper	Lower			
15 June—2 Sept.	Fambridge	nil	7	9:245	nil:2	nil:2
	Purleigh Shore ...	1	10	1,950:6,700	1:nil	nil:2
	Althorne Creek ...	11	8	148:2,250	2:3	1:15
	Creeksea	nil	12	711:433	2:7	nil:1
	Shop Laying	nil	9	2,200:3,000	2:nil	nil:5
	Broadrakes	nil	3	220:2,600	2:nil	nil:4
		12	49			

are even more harmful in certain places. Most sessile animals settle more abundantly on lower than on upper surfaces but *Elminius* shows no discrimination in this respect.

The preference for lower surfaces shown by *O. edulis* on Essex oyster beds is in agreement with the bulk of previous work on the setting behaviour of oysters. Pending further evidence it may perhaps most reasonably be regarded as normal behaviour, which may be modified in the presence of heavy settlements of other organisms and reversed by turbulence and certain abnormal conditions.

Gregariousness.

Experiments in the Conway tanks showed that larvae set in much greater numbers on shells which bore previously settled spat, than on similar shells from which the spat had been removed. This gregarious tendency was most marked when the spatfall was light, for when numerous larvae were setting they quickly covered both spat-shells and bare shells alike. Apparently larvae in the searching phase proceed more readily with setting if there are already spat nearby, perhaps as an olfactory response to some water-borne secretion from the spat (Cole and Knight Jones, 1949).

It is remarkable that this gregarious tendency should first have been demonstrated under tank conditions where the oysters were already somewhat crowded, rather than on oyster beds. Several Essex oystermen have observed particularly heavy falls of spat on well-stocked grounds. Mr. Rice, the Roach River Oyster Company's foreman at Burnham-on-Crouch, drew attention to the fact that in 1947 spat were fairly abundant amongst the Brittany oysters which were thickly laid on his grounds, but practically absent from other grounds in the neighbourhood which were sparsely stocked. He deduced from this fact that the Brittany oysters had bred successfully and he regarded the spat which were attached to them as their progeny. Mr. Barber and Mr. Francis, foremen of the Colne River Oyster Fishery Co., have noticed that during several summers moderate falls of spat have occurred on their well-stocked grounds, whilst the spatfall on large sparsely-stocked areas was negligible, although they had successfully kept the shell there free from silt by dredging and harrowing. They volunteered this information in support of the idea that spat settles almost immediately after liberation, an idea which is widely-held amongst Essex oystermen, but erroneous. Korringa (1941) showed that the planktonic stage of *O. edulis* in the Oosterschelde lasts from six to fourteen days, varying with temperature. It is of similar duration in Essex waters.

In the Burnham-on-Crouch district during 1947 the numbers and viability of larvae liberated were very low, probably as an after-effect of the severe winter. In spite of favourable conditions only a few reached settlement size, the majority of these about the end of July. On 13. and 15. August dredge hauls from the lower reaches of the R. Crouch and from the R. Roach were examined, to assess the quantity and distribution of the spatfall. A sample of shells, the majority of *O. edulis*, was picked out at random from each location and the entire surface of each shell was examined with a hand lens. The examination occupied several hours on each day and it is unlikely that many spat escaped observation, although some were so small that they must have settled only a few days earlier. Some live oysters from each location were also examined.

Table 3. Distribution of Spatfall in Rivers Crouch and Roach, 1947.

Date	Locality	Sample consisted of: Shells	Sample consisted of: Oysters	Spat on: Shells	Spat on: Oysters	Density of stock
13. Aug.	Mouth of Crouch	10	5	0	1	Very sparse
	Holliwell	40	20	5	0	Rather sparse
	Bush Shore	30	10	4	0	Sparse
	Creeksea	10	0	1	0	Very sparse
15. Aug.	Nr. mouth of Roach	3	0	0	—	None–almost bare mud
	White House Hole	20	10	2	0	Rather sparse
	300 m. below Paglesham Pool	24	2	1	0	Sparse
	50 m. below Paglesham Pool	19	15	40	7	Very dense
	Inside mouth of Paglesham Pool	21	2	37	5	Fairly dense
	Shop Laying (500 m. above Paglesh. Pool)	21	4	2	0	Very sparse

Details of the samples examined and spat recorded are given in Table 3. The only place where spat were common was close to the mouth of the creek known as Paglesham Pool. Immediately outside this creek about 500,000 Brittany oysters had been laid in a comparatively small area. The sample which contained most spat was obtained from amongst these oysters. Another sample which contained many spat was obtained less than 100 metres away, within the mouth of the creek, on ground which had also been fairly well stocked with relaid brood oysters. All the other grounds visited were sparsely stocked and the numbers of spat found on them were negligible. It was a striking fact that the spatfall was very slight only a few hundred metres away from the well-stocked areas. There appeared to be no differences in condition of the bottom or exposure to currents which could have accounted for this unequal distribution of the spatfall. A part of the Shop Laying, where the spatfall was negligible in 1947, caught a particularly heavy spat the following year after it had been stocked with 100,000 Brittany oysters, proving that it is not inherently unsuitable as a spatting ground. In 1947 fully-developed planktonic larvae had been rather uniformly distributed throughout the Rivers Crouch and Roach and must have been carried several miles during each tidal cycle. It seems most probable that the restriction of the spatfall to the small area at the

mouth of Paglesham Pool resulted from the gregarious tendency.

The mortality which followed the severe weather early in 1947 was so heavy that very few live oysters remained on any of the Ministry's grounds in the Burnham district. None could be found at Purleigh Shore and Fambridge. There appeared to be no live oysters in the River Crouch above the upper end of Bridgemarsh Island. The spatfall of 1947 was a failure. Oysters which were laid during the spring of 1948 in dense patches on widely separated grounds, were therefore surrounded by relatively vast unstocked areas. The majority of these oysters were 3 years old, obtained from Brittany and from the oyster breeding experiments in the Ministry's tanks at Conway. They were laid as follows (numbers are approximate):—

Fambridge	10,000	Conway 3-year-olds.
Purleigh Shore	10,000	Conway 3-year-olds.
Creeksea	2,000	Conway 4-year-olds.
and	3,000	Native oysters.
Bush Shore	10,000	Native brood.
Broadrakes	10,000	Conway 3-year-olds.
Common Shore	5,000	Conway 3-year-olds.
Shop Laying, S. end	100,000	Brittany 3-year-olds.
Shop Laying, N. end	5,000	Conway 3-year-olds.

The Brittany's were laid on a strip of ground measuring about 100×20 metres, the remainder on square patches of about 15×15 metres. These small areas were therefore stocked at densities of about 50 oysters per square metre.

Some spat settled in July and August, 1948. By September the spat were large enough to be counted easily. Short hauls, about 20 metres long, were then made with several dredges across each densely-stocked area. The dredge-bags came up full of oysters and cultch shells. A sample of shells which were clean and bore a few barnacles, proving that they had not been covered with silt whilst lying on the bottom, were taken at random from the bag which contained most oysters. Then similar hauls were made on ground 50 to 100 metres away from the densely-stocked area, which was otherwise similar in nature of bottom, depth and distance from shore. The dredge-bags came up with shells only. From these a similar random sample was taken.

The shells were examined in the laboratory with hand lenses and the spat counted. With two exceptions (Broadrakes, 27. Sept. and Fambridge, 28. Sept.) there were always more spat from the densely-stocked areas, usually about twice as many as from the neighbouring areas where oysters were scarce or absent (Table 4). The earlier samples (2. Sept.) showed greater differences than later samples from the same grounds. There is always a heavy mortality amongst recently settled spat and much of this is probably due to the predatory activities of oyster pests, which may be expected to congregate, as *Urosalpinx* does, where oysters are most numerous.

The spatfall was particularly heavy on the sample taken from the large patch of Brittany oysters. The sample with which this was compared was taken from ground which was about 100 metres below the Brittany's, 100 metres above the Shop Laying Conways and 400 metres above the densely-stocked area at the mouth of Paglesham Pool, which contained several hundred thousand Brittany and native oysters. Thus this ground, although containing practically no oysters, had particularly densely stocked grounds nearby, above and below it. The spatfall on this ground was heavier than that on the small patches of Conway oysters on Common Shore and Broadrakes, less than a mile up-river. This suggests that the presence of very large numbers of densely-laid oysters encourages settlement in the vicinity up to a considerable distance, supporting the idea that olfactory perception may be involved.

Gregariousness and the Reclamation of Derelict Oyster Grounds.

The Ministry has taken over a laying in the S. Channel of Tollesbury Fleet which is said to have been

Table 4.

Comparison between Numbers of recently settled Spat on similar Samples of Shells from densely stocked ground and from similar ground 50–100 metres away where Oysters were scarce.

Date	Locality	From densely stocked ground			From ground where oysters were scarce or absent		
		No. of Shells	Distribution of spat on shells which bore spat	No. of spat per 10 shells	No. of Shells	Distribution of spat on shells which bore spat	No. of spat per 10 shells
2. Sept.	Fambridge	11	6,1,3,2	10·9	13	1,1,1,1	3·1
	Purleigh Shore	9	7,1,4,3,2,3	22·2	16	1,2,2	3·1
27. Sept.	Bush Shore	21	4,2,1,2,1,1,1,1,1,3,1,2	9·5	20	1,1,2,1,1,2,1,1	5
	ShopLaying,(Brittanny's)	19	1,5,2,9,12,19,2, 27,2,1,4,2,2,8,1	51·1	19	1,4,2,1,7,9,19, 2,5,1,1,1	28
	Common Shore	20	1,6,1,4,3,3,5,1,5	14·5	20	1,1,1,1,3,8	7·5
	Broadrakes	19	2,1,2,2,2,2,1	6·3	21	2,1,2,4,1,1,3,1	7·1
28. Sept.	Creeksea	20	1,2,1,1,3,1,1	5	20	2,1,1,1,1	3
	Purleigh Shore	20	1,1,1,1,3,1,2,2,4	8	20	2,1,1	2
	Fambridge	20	1,1,2	2	20	1,1,1,1,1,1,1	3·5
			Totals ...	129·5			62·3

formerly productive oyster ground but which is now covered with deep mud. There the most common members of the macrobenthos are *Sabella pavonina* and *Ascidiella aspersa*, the latter occurring in clumps, anchored by long rooting processes of the test. Oysters are practically absent.

At the beginning of May, 1948, a small area about 15 metre square, near the edge of the laying but never exposed at low water, was cleared of *Sabella* and *Ascidiella* by dredging. Between 3. and 11. May 300 bags of bleached shell were spread over this patch. On 14. May 2,800 oysters from Conway, the majority 3-year-olds, were laid upon it. At the same time a similar patch 100 metres away was cleared. Between 17. May and 23. June 300 bags of shell were spread over this second patch, but no oysters were added to it.

The main spatfall occurred in August.

On 11. October short dredge hauls were made both on the stocked patch and the unstocked patch. Six dredge hauls on the stocked patch produced 50 oysters and 10 recent clocks. Most of the clocks were bare inside, suggesting that their late occupants had died since the spatfall. Four of the clocks bore spat on their inner surfaces and were examined carefully. The distribution of spat upon them was as follows:—

	Totals
Inner surfaces 24,9,25,18	76
Outer surfaces 12,2,15,8	37
	113

A random sample of 150 cockle shells (*Cardium edule*) and 50 others (the majority small *O. edulis*) was taken from each patch and examined. The distribution of spat on those shells which bore spat was as follows:—

Stocked patch		Totals
150 cockle shells	1,1,1,1,4,1,4,1,1,3,9,1,2,1,2,1,2	36
50 other shells	2,1,1,31,1,17,3,12,1,9.....	78
		114

Unstocked patch		Totals
150 cockle shells	1,1,1,1,1,1,1,1,2,1,2,1,5,1,1,1,2,2	26
50 other shells	1,2,4,1,1,2,2,1	14
		40

Nearly three times as many spat were recorded from the stocked patch as from the unstocked patch, or nearly six times as many if the spat on the clocks is included. The only difference between the patches was that the shell on the unstocked patch had been laid somewhat later than on the stocked patch (see above) but all shell had been laid at least a month before the main spatfall. The shells on the stocked patch were somewhat more overgrown and muddy than those on the unstocked patch but it is unlikely that this slight difference could have led to the heavier spatfall on the stocked patch and there seems little doubt that it was due to the gregarious tendency, in view of the other evidence pointing to the existence of such a tendency.

Evidently plans for making derelict oyster grounds productive should take into account the gregarious tendency. It would be unwise to spend time and money in cleaning a ground and spreading cultch upon it and then to leave it unstocked, trusting to the fecundity of the oysters on neighbouring grounds and the wide distribution of their planktonic larvae to populate it. Admittedly, if the spatfall is heavy the gregarious tendency will probably be masked and spat will settle everywhere with little discrimination, but such heavy falls of spat are unlikely to occur until breeding stocks in British waters become much larger than they are at present. With present stocks no more than moderate falls of spat can be expected and under such conditions the numbers settling on unstocked ground will be comparatively few. The reclamation of derelict ground will be greatly aided by relaying brood oysters. Not only will this add to the breeding potential of the area, ensure that the ground is cleaned again, as the oysters are caught, and provide an early source of revenue. It will also lead to a considerably increased spatfall, for many more larvae will choose to settle there.

Summary.

When settlement of other organisms was sparse settlement of oyster larvae was consistently heavier on the lower than on the upper surfaces of horizontal slates exposed for weekly periods in Essex creeks. When barnacles were settling abundantly the oyster larvae which settled amongst them did not show such consistent discrimination between upper and lower surfaces, but still settled more heavily on the lower surfaces.

The upper surfaces of slates left undisturbed for several weeks became covered with thick layers of filamentous diatoms and silt in most localities. Few spat were found beneath such layers.

The gregarious tendency during settlement, which was demonstrated experimentally at Conway, appears important on oyster beds. Random samples of shells from well-stocked areas bore many more spat than similar samples from unstocked areas.

Spat was more abundant on an area of derelict ground which had been cleaned, covered with cultch shells, and stocked, than on a neighbouring area which had been similarly treated but left unstocked.

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7.

Difficulties Encountered in Tank-Breeding of Oysters (*Ostrea edulis*).

By

P. Korringa

Introduction.

That a natural population of oysters easily suffers from overfishing has generally not been understood until it was too late. It is true that one single oyster in such a population may produce several hundreds of thousands of larvae in the summer season. Very many of these larvae, however, meet an untimely death in the stomach of some plankton eating animal. Many others are carried by the currents to regions where setting and survival is impossible. Thus a limited percentage of the many larvae (about 5% under very favourable hydrographical and biological conditions) reach the mature phase, ready to settle down. Inconceivably few of those mature larvae succeed in finding a suitable collector to attach themselves to, the others perish. Even when oystermen offer the larvae great quantities of collectors, as in the basin of the Oosterschelde, Holland (about 3,000,000 tiles and 10,000 m.^{3} of mussell shells annually) only about 1% of the mature larvae manage to settle down on these collectors. Many of these perish in the perilous first months of their sedentary existence. An ample production of larvae is required to lead to a fair set. Oyster farmers cannot be satisfied with a mere sprinkling of spat. They need enough young oysters on their collectors to pay amply for their spat producing operations. This is difficult or impossible in overfished districts.

It need not surprise us that the possibility was considered of rearing larvae in ponds or tanks in those countries where the natural set had become insufficient or negligible. No currents can wash the larvae out of the tanks to an unsuitable area. Predators, feeding on oyster larvae, could be kept down very effectively. Further a far greater quantity of collectors could be offered per unit of water than in the open bays, so that the chance of the larvae finding a collector could be enhanced to no small extent. The larvae produced by only a few mother oysters would be sufficient to obtain hundreds of thousands of young oysters.

Recently other considerations have come to the fore. Little attention has been paid so far to the possibility of selecting special strains of oysters, characterized by superior qualities in growth, flavour, resistance to diseases, and so on. We may rest assured that research on heredity and selection in oysters eventually will yield important results to the oyster industry. In such research one ought to be able to rear the larvae of limited numbers of well selected oysters. To this aim reproduction in ponds or tanks is the only feasible method.

Though theoretically no reasons can be conceived why the rearing of oyster larvae in tanks should not be possible, the many attempts made in different countries usually led to failure, sometimes alternating with an occasional very moderate success. It appeared to be very difficult to find out which factors govern success and failure in the tank-breeding of oyster larvae.

The Food of the Oyster Larvae.

In many early experiments one tried to introduce fresh sea water, bearing the natural food of the larvae, into the rearing tanks, at the same time draining off the excess water through sand or porous filter blocks. It was impossible to establish a good flow of water without dragging the tiny larvae to the filters. It appeared to be impossible to maintain an equal distribution of the larvae in these tanks.

In experiments carried through at Port Erin, Isle of Man, it was demonstrated that oyster larvae can be grown successfully if fed with cultures of small naked greenish or brownish nannoplanktonic flagellates. In some cases there was success in rearing to settlement about 90% of the larvae originally introduced in the plunger jars. In recent years Imai (*in litt.*) found that feeding with small colourless flagellates (Monas), grown by adding some soluble starch

to sea water, may likewise lead to success in growing oyster larvae.

It is possible that many failures in rearing oyster larvae in tanks should be ascribed to lack of adequate quantities of the appropriate naked flagellates, so that the oyster larvae suffered from starvation and died. One should remember that the density of larvae in the tanks is usually far greater than in open water, so that the number of food organisms must be correspondingly higher.

It is Dr. H. A. Cole of the Conway Fisheries Experiment Station who should be given credit for inventing the method of enriching the water with minced crabs, which leads to a rapid development of the required flagellates, so that the oyster larvae in his tanks develop well, and settle on the collectors offered.

Though this system to produce oyster spat in tanks regularly leads to good results in Conway, Dr. Cole complains that he repeatedly observed that differences in the viability of the larvae may interfere with normal development. Further Dr. Cole was not in a position to give a satisfactory explanation for the noteworthy fact that setting was regularly accomplished in the Conway mussel purification tanks, which are about 8 feet deep, but practically always led to failure in similar tanks half as deep, though the very same water and the very same methods were used.

Experiments in Holland.

In the year 1946 I started to experiment myself in the rearing of oyster larvae in tanks, though I could only use tanks of 3 to 4 feet deep, and though I could not fill these with offshore water, which Dr. Cole claims to be a necessity. Inshore water, according to him, might easily show a profuse development of non-motile algae, indigestible to oyster larvae, instead of a culture of naked flagellates.

I was successful, however, in producing a dense culture of nannoplanktonic flagellates in the tanks at Tholen, following Dr. Cole's procedure. Non-motile algae and diatoms were very rare in the tanks throughout the experiment. Oyster larvae were amply produced by the mother oysters placed in the tank. Temperature, salinity and pH left nothing to be desired. Contrary to expectations the oyster larvae in the tanks did not develop at all. They soon showed symptoms of ill-health and died. No spat was obtained in the 1946 experiment.

In a search for the factor which should be held responsible for this complete failure, I measured the quantity of oxygen present in the water near the bottom and near the surface of the experimental tank. It may be assumed that during broad daylight flagellates produce ample oxygen, but that they consume oxygen, like the oyster larvae, the adult oysters, and other creatures, during the dark hours of the night. This idea was corroborated by a series of observations carried out during 24 hours. Though a marked drop in the quantity of oxygen could be observed in the second part of the night, the values measured in the tanks always remained higher than those observed simultaneously in the open Oosterschelde. Therefore it was considered highly improbable that a lack of oxygen could have been the cause of the 1946 failure to rear oyster larvae in the experimental tank at Tholen.

Observations made in the laboratory on the swimming behaviour of the larvae demonstrated that oyster larvae are inclined to rest now and then, and sink down with either the valves closed, at 0·8 cm./sec., or with the velum expanded like a little parachute, at 0·4 cm./sec. They seldom drop for more than 50 cm. in succession and usually start swimming upwards again after dropping for half a minute. Moreover, larvae dropped on the bottom could easily rise again, and were by no means trapped on the bottom of my glass tubes and containers. I cannot see how the typical swimming behaviour of oyster larvae could be held responsible for their failure to develop normally in a tank of about 4 feet deep.

The only factor I regularly checked during the 1946 experiment which showed figures clearly different from those observed in open water, was the quantity of oxygen. The oxygen figures for the tank actually were higher than those for the open Oosterschelde, and often supersaturation prevailed in the tanks. Though it seemed difficult to explain the failure to a slight excess of oxygen, I decided to keep the oxygen level down to more normal proportions in experiments carried out in the same tank in the year 1947. I presumed it might be feasible to check oxygen production by keeping the number of flagellates within bounds. The latter could be achieved by adding fewer crabs. I was able to keep the number of flagellates between 10,000 and 20,000 per cc. and to avoid the figures of 50,000 to 100,000 per cc. attained in the 1946 experiment. This resulted in a more modest oxygen production during the daylight hours, and supersaturation values were seldom observed during the 1947 experiment. The course of events during 24 hours sampling resembled that observed the year before, but was at a lower level, closer to that observed in the open Oosterschelde. The 24 hour rhythm of the oxygen level in the centre of the Oosterschelde appeared to show a far narrower amplitude than that observed in the tanks, no doubt because the number of flagellates in the tanks was about 10 times as high as that in the open Oosterschelde.

In the year 1947 factors such as temperature, salinity and pH in the tank showed normal figures. The oyster larvae appeared in due time. They developed well. Large and mature larvae were observed in great numbers. The setting on the collectors offered was intense.

This result could easily lead to the belief that the key to open up spat production in shallow tanks had been found. One should provide for ample production of small naked flagellates to feed the oyster larvae but the production of flagellates should be kept within

bounds, to avoid development of too extreme conditions injurious to oyster larvae.

I could adduce no evidence that oxygen itself is injurious to oyster larvae. In laboratory experiments the larvae even survived in water containing 200 and 300% of the normal saturation value of oxygen. Efforts to demonstrate the presence of peroxides, which might be dangerous, had a negative result. Though a modest oxygen production in the tank and successful larval development and setting ran parallel in the 1947 experiment, it does not follow that oxygen itself was the limiting factor in the 1946 experiment. It just shows a great difference in the intensity of carbon-dioxide assimilation by the tiny flagellates. Apart from oxygen other products of assimilation or dissimilation are released by flagellates and kindred minute organisms. Though little is known about these organic metabolites, there is ample evidence that several of them are toxic to other organisms. Recently Loosanoff and Engle demonstrated the presence of similar organic metabolites produced in dense plankton cultures, which proved to be toxic to adult oysters. This led me to assume that too dense populations of flagellates in experimental tanks hamper the development of oyster larvae by producing dangerous quantities of toxic excretions. A high level of oxygen is probably only an indicator of too vigorous assimilation activities which may lead to concentrations of external metabolites injurious to oyster larvae.

This view corresponds with the success obtained in tank-breeding by Dr. Imai, at Sendai, Japan, (*in litt.*). This able investigator keeps down carbon-dioxide assimilation by covering his tanks and by making use of colourless flagellates produced by addition of some soluble starch to the water. His oyster larvae develop well as a rule in his shallow tanks and he has been the first to cross-breed different strains of oysters in efforts to produce more and better varieties.

Further Difficulties.

The results of my 1949 experiments point in the same direction. I used the same tanks at Tholen and planned to duplicate the 1947 experiment by keeping the flagellates within bounds. Instead of starting with about 2,000 flagellates per cc., as in the years 1946 and 1947, a normal figure for the open Oosterschelde, the water which entered my tank gave counts of 20,000 to 30,000 flagellates. Moreover, some "wild" oyster larvae were washed into the tank, some of which showed the very same signs of ill-health I observed in the tank in the year 1946. I did not add any crabs or other manure. The oyster larvae produced in the tank did not develop, and died after showing the typical signs of ill-health (loss of colour, grey hue and large hyaline spots).

I repeatedly tried to fill the basin anew with water showing a more normal number of flagellates and devoid of diseased "wild" larvae, but was not successful in this. Careful sampling demonstrated that a body of water showing only slight tidal movements was situated near the eastern bank of the river Eendracht, a branch of the Oosterschelde on which the town of Tholen is situated. I drew the water for my experimental tank from this stagnating body of water, rich in flagellates (15,000 to 30,000 per cc.) and containing the characteristic diseased larvae. Its oxygen level showed rather high figures too, but supersaturation did not occur. The swift flowing water in the centre of the river Eendracht showed normal features: a modest number of flagellates (2,000 to 5,000 per cc.) and healthy oyster larvae. Unfortunately I had no siphon at my disposal to fill the experimental tank with this water.

I tried to find out whether the presence of toxic excretes could be demonstrated by chemical analysis. As I possessed no information about the chemical structure of the excretes, I measured the total quantity of "dissolved" organic matter after passing the water through a Berkefield filter. Though the figures thus obtained slightly surpass those measured in the water of the open Oosterschelde, no general accumulation of dissolved organic matter could be demonstrated in the experimental tank or in the body of toxic water at the eastern bank of the river Eendracht. Probably bacteria see to it that excess organic matter is broken down in due time. Before we know more about the true nature of the toxic external metabolites produced by the flagellates, we cannot measure how much of them is present among the "dissolved" organic matter in experimental tanks and open waters.

The 1949 experiment clearly demonstrates that toxic water is not limited to experimental tanks, but may also occur locally in nature. The observation of diseased larvae, combined with an abnormally high number of flagellates, may be used to identify such water. Great care should be taken to fill experimental tanks with pure water, if possible "offshore" water, and to avoid rich and more or less stagnant water locally encountered along the banks of bays and inlets. Water initially containing more than 5,000 flagellates, or a correspondingly large number of other phytoplankton, should be mistrusted as it may contain toxic concentrations of phytoplankton metabolites from the first day the tanks are filled.

Summary.

The tank breeding of oyster larvae is desirable for several reasons. Experimental tanks with running sea water never led to success. The provision of an adequate amount of the right food for oyster larvae, small naked flagellates, is possible since Cole found a method to control the number of these organisms in experimental tanks. Difficulties may still be encountered, especially in shallow tanks. In all probability the main reason for failure in enriched tanks is the accumulation of toxic external metabolites produced by flagellates or other phytoplankton organisms. It could

be demonstrated that even in open water similar toxic conditions may prevail and that the greatest care should be exercised in choosing the right kind of water for tank-breeding experiments.

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8.

The Sanitary Control of Shellfish in England.

By

H. P. Sherwood

In this paper the writer's object is to provide material for discussion by reviewing briefly the development and present features of sanitary control of shellfish in England.

The main facts about pollution of molluscan shellfish by sewage are now firmly established and well known. Yet about some of its aspects there is still little agreement. To distinguish between the extremes of safe and dangerous sources of shellfish has never been a serious difficulty, indeed the presence of a sewer so placed that discharges from it are carried over an adjacent shellfish bed is surely ample evidence of danger, but where "safe" and "dangerous" merge into a third category of "doubtful" leaves much scope for individual opinion. The difficulty of assessing the significance of the quantity and quality of an effluent, of tidal currents, distance and dilution, encourages the administrator to turn hopefully to bacteriological results for guidance. He does so readily, not only when in genuine doubt, but on all occasions as a basis for sanitary control. Hence the demand for a bacteriological standard, and for a recognised method of examination upon which a standard must depend.

The international aspect of sanitary control of shellfish may be noted first. As a country importing shellfish England has long been interested in the possibility of an internationally recognised method and standard, and no doubt exporting countries are similarly concerned. It was in recognition of such a need that the Conseil International in 1932 arranged a conference of shellfish experts at Middelburg, Holland. As recorded by Bigger (1934) it was noted that in the seven countries represented there, entirely different methods were in use, none of which was official in any country. To meet this situation a resolution by Dr. Bigger (Eire) who had recently made a special study of the sanitary control of shellfish (Bigger, 1929), was adopted, whereby the members agreed to control their own methods of bacteriological examination by using along with it a medium devised by Salle (1930), and to observe certain rules of technique necessary to produce comparable results. As applied to shellfish tests Salle's medium was intended to be both quantitative and selective. It had been designed for use in water examinations for the confirmation and differentiation of coliform organisms truly indicative of faecal contamination, and those often present in sewage effluents (and so in shellfish) though not necessarily of faecal origin. According to unpublished reports, trials of this medium in England, Holland, and the United States were disappointing, as were those by Bigger (1934). In the absence of a further conference results obtained in other countries have not become available.

In the United States and in some other countries the sanitary control of shellfish has received much attention from the Central Government or from public health or shellfish associations, or from all these organizations, and comprehensive recommendations have been drawn up and adopted. In England developments have been on somewhat different lines. Under powers derived from its ancient Charter, the Fishmongers' Company has for many years controlled the entry of shellfish to the London markets. Bacteriological examinations begun in 1902, in conjunction with topographical surveys, have yielded a fund of information which enables the Company to advise local authorities about sources of shellfish when requested. The Company has thus exercised widespread influence in improving the sanitary standard of shellfish offered to the markets.

The Central Health Department (then the Local Government Board) caused surveys of all shellfish beds to be made (Bulstrode, 1896, 1911), but it was not until 1915 that the first administrative measure, the Shellfish Regulations, were made by the Ministry of Health under the Food Act, 1907. These regula-

tions gave power to local authorities where shellfish are landed, to make orders for the closing of beds or layings shown to be dangerous, but they included no guidance as to assessment of danger. A revision in 1934 added clauses permitting the sale of shellfish which had been either relaid, subjected to purification at an approved installation, or sterilised by heat under pressure. Shellfish from closed beds could still be gathered provided they were not intended or offered for sale, and this loophole has sometimes made an order difficult to enforce. Closing orders already made affect about thirty areas. They followed reports mostly from inland health authorities of illness associated with shellfish from the sources in question. Other areas have been closed by the Ministry of Health under the Food Act in the absence of action by the local authority concerned. In some other areas similar action appears to be overdue.

It remains to be mentioned that in addition to the control exercised by the Fishmongers' Company, the Ministry of Health and local authorities, the health authority of any city which has included the necessary powers in its City Act may prohibit the sale within the city boundary of shellfish from sources not already closed, which are considered to be dangerous to public health.

An important step, also in 1915, was the adoption by the Fisheries Department of the method of mussel purification devised at Conway by Dodgson (1928) and approved by the Ministry of Health, for treatment of mussels otherwise banned from the markets under closing orders. Under an enactment in 1932, local authorities were empowered singly or jointly to raise loans for the purpose of erecting shellfish purification stations for carrying out the treatment thus approved. Thereby the method introduced at Conway has been extended successfully to mussels at Lytham on the Ribble estuary, and with certain necessary adaptations for the purification of oysters, at Brightlingsea, near Colchester. Plans for stations elsewhere are under consideration. For small fisheries approved purification is not economically feasible, but conveyance of shellfish to purification centres is one way of overcoming this difficulty, and in any case mussels from closed areas are in regular demand for use as bait. Although the food market for mussels is almost entirely for the fresh uncooked article, whatever the subsequent treatment in the home may be, there must be means of sterilising them without impairing their flavour, as in the case of milk. Together with freezing this treatment would provide for distribution of a fresh, palatable and safe product. Trials of some such method by a private firm are already in progress. Cockles, of which there are three large and several small fisheries in England are eaten cooked, and are in many places acceptable already cooked and salted. Danger from pollution is readily removed by boiling them for two or three minutes.

The Fisheries Department being concerned on behalf of inshore fishermen, has long realised that restoration of public confidence in shellfish, seriously impaired in the past by two notable outbreaks of enteric fever derived from oysters, could largely be restored by elimination from the food markets of all shellfish of doubtful purity, greatly to the ultimate benefit of the shellfish industry. The public health situation received attention at the annual representative meeting of the British Medical Association in 1936, when the following resolution was sent to the Ministry of Health:

> "The time has now arrived when the Ministry of Health should be requested to make regulations prohibiting the sale for human consumption in this country of molluscan shellfish whether home produced or imported, which are not certified to have been cleansed by the recognised method at a station approved for the purpose by the Ministry of Health."

The ideal of approved purification of all shellfish destined for human consumption, whatever their source, has become remote because of the present high cost of providing the necessary installations. Less costly equipment is clearly needed. It has been suggested that suitably placed storage ponds should be made or adapted for improving the sanitary condition of oysters, the period of deposit being adjusted according to the water temperature.

To avoid interruption of sales caused by occasional failure of oysters from sources not officially closed to reach the bacteriological standard of purity adopted by the Fishmongers' Company, some producers have installed small privately owned storage installations, consisting of tanks or tubs supplied with circulating sea water, in which the oysters remain for two or more days. Others have done likewise, aware of the need to keep abreast of their business competitors. A feature of these installations is the use of ozone to maintain the sanitary conditions of the sea water, there being a deep rooted though demonstrably unfounded prejudice against chlorine for this purpose. Installations of this type have not been approved by the Ministry of Health under the permissive provisions of the Shellfish Regulations for treatment of oysters from closed areas; they embody features which are open to serious criticism. They have, however, largely eliminated the interruptions previously experienced.

It will be observed that although there is no precise general system of sanitary control of shellfish in England ample powers are available for protection of the public health. In the exercise of these powers the authorities concerned have not readily adopted measures which might deprive fishermen of their chosen livelihood. Potential danger, viz. the proximity of shellfish to sewer outfalls, has seldom been accepted as justification for action; nearly always epidemiological evidence of pathogenic illness conveyed by shellfish has been the stimulus, and administrative action has always been preceded by bacteriological sampling and topographical enquiry.

A reliable classification of all shellfish areas according to their sanitary condition would serve the inter-

ests both of public health and the fisheries. It is accordingly the intention of the Fisheries Department to survey the country's shellfish resources with special reference to pollution. In preparation for such a survey, and to further the adoption of a standard test, existing bacteriological tests and their defects have been reviewed, and a new technique devised by CLEGG and SHERWOOD (1947). The need for a generally recognized test was recently expressed by bacteriologists of the Public Health Laboratory Service, there being an increasing concern on the part of health authorities in the sanitary condition of all foodstuff. A committee has now been formed by the Laboratory Service with the object of making recommendations for a standard test, and as a starting point the proposed new technique is being tried in several laboratories.

A description of the new test would be out of place here, but it may be mentioned that its purpose is to indicate as quickly and accurately as possible the degree of pollution in the shellfish examined, due regard being paid to the volume of flesh in each case. The criterion of pollution is the content of "faecal coli" (*Bacterium coli*, type I, WILSON, 1935). Roll tube cultures made in a suitable medium are immersed for incubation in a water bath kept accurately at a temperature of 44° C. A count of the red colonies produced by the organisms sought can be made after twelve hours. The selective value of incubation at 44° C. in the examination of water was stressed in a comprehensive review by BATTY-SMITH (1942), and of shellfish by SHERWOOD and CLEGG (1942).

The use of routine bacteriological tests at the markets as a basis for sanitary control of shellfish purified at approved stations is of doubtful value. At such stations the essential requirement is conscientious observance of the correct routine together with adequate supervision. The value of the approved treatment has been fully established, and temporary closing of a station as an "insanitary area" in consequence of an unfavourable test would be futile. In any case temporary suspension of marketing in consequence of a bad bacteriological result is not an ideal form of sanitary control. An increasing tendency is observable on the part of some health authorities to assess the sanitary condition of the source of shellfish received in their area, by reviewing bacteriological results obtained over a long period. In this way bacteriological tests are valuable in conjunction with topographical data, particularly for the disclosure of new sources of pollution, and in the tracing of secondary pollution arising between the source and the market, as well as for assessing new sources of supply. A serious limitation in the use of bacteriological tests is their failure to distinguish human from other faecal contamination. Much information about sources of pollution can be obtained, however, by depositing samples of shellfish of known initial purity in sterile cages at selected points for appropriate periods during a tidal cycle, and recovering them for bacteriological examination. The concentration of organisms by the shellfish gives this method advantages over the simple procedure of water sampling.

The absence of a generally accepted bacteriological standard for shellfish in England is a measure not only of the difficulties which beset anyone who attempts to devise a standard suitable for all requirements, but also of the diversity of bacteriological methods in use. The difficulties were fully discussed by DODGSON (1928). The subject involves details of the methods forming the basis of the various standards which have been used or proposed. It is noteworthy that HOUSTON (1904), a pioneer in shellfish sanitation, who advocated the testing of decimal dilutions made from a number of oysters pooled together, attached much importance to topography. He classified oysters in six sanitary categories, and tentatively suggested two standards for comparative purposes only: a "lenient" one applicable to shellfish from "good" sources substantially free from faecal pollution, and a "stringent" one for "bad" sources where pollution is known to be present, viz. less than 1,000 and less than 100 *B. coli* per shellfish respectively.

The method of examination used by the Fishmongers' Company (EYRE, 1924) classifies samples on a basis of percentage clean, according to the presence or absence of *B. coli* in a specified amount of fluid from ten shellfish tested individually: for oysters, 0·2 cc.; for mussels 0·1 cc. Thus if four out of ten tests in any one sample result positively the sample is described as "60 per cent clean", and is just passable for sale without further comment. Consignments yielding samples 30 per cent clean or less are condemned forthwith, and those between these two percentage are held up pending a further analysis and, if necessary, a revision of the topographical examination of the layings. This procedure has served a useful purpose, but the test itself gives little information as to degree of pollution, and according to DODGSON (1928) and BIGGER (1929) it is markedly subject to the element of chance.

In one city health department a source of shellfish is considered unsatisfactory if samples from it are found to contain over a period of some weeks an average of more than 10 *B. coli* per cc. of shellfish. The *B. coli* figure is determined by an adaptation of the "most probable number" technique devised for water examinations. This method has disadvantages associated with the use of a liquid medium, and gives widely varying results with the same material.

BIGGER (1934) introduced a standard corresponding roughly to that of the Fishmongers' Company, on the basis of a new method from which he had eliminated most of the unsatisfactory features of earlier tests. This method, by which ten shellfish are examined individually, is at a disadvantage in requiring the use of 60 tubes per sample.

In considering the application of bacteriological standards to shellfish control it has to be remembered that local health authorities, at any rate of inland

districts, cannot themselves undertake topographical investigations, and have to depend upon bacteriological findings. So long as shellfish of doubtful sanitary quality may reach his markets, a medical officer of health would be lacking in vigilance if he failed to have samples of shellfish tested, and to decide what degree of pollution he must regard as dangerous. If he has powers under a Municipal Act, he may, as in one large English city, admit only shellfish which have been purified at approved stations. If not, unless he can instance illness attributed to a particular source which he may consider dangerous, he may fail to have it closed by the coastal authority concerned. He must then try to maintain his standard by exercise of persuasion with market dealers.

Under present conditions shellfish from areas closed to the markets of one municipality may be accepted in those of another. For this reason it seems that there would be advantages in the adoption of a recognized system of classification of sources, without in any way relieving local health authorities of their responsibilities. In any case the need for a generally accepted bacteriological technique and standard remains. For a standard, freedom of 1 ml. quantities of shellfish from "faecal coli" in the majority of a series of samples tested, as in purified shellfish, is a sound desideratum, with greater latitude in respect of any sources known to be free from human pollution.

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9.

Le Contrôle Sanitaire des Huîtres, Moules et Coquillages.

Par

Louis Lambert.

L'eau de mer, l'eau du large, n'est pas stérile, bactériologiquement pure, mais il est reconnu qu'elle ne contient pas de microbes pathogènes à l'homme, en particulier le redoutable bacille d'Eberth ni ses cousins paratyphiques.

Il n'en est malheureusement pas de même près des côtes où elle est trop souvent souillée par les écoulements des agglomérations. Cette souillure atteint parfois des gisements naturels sur lesquels vont pêcher innocemment les baigneurs ou moins innocemment certains pêcheurs.

D'autre part, pour diverses raisons techniques, facilité d'accès, proximité des moyens de transport, etc. ... les expéditeurs et parqueurs ont tendance à se rapprocher des dites agglomérations, donc des causes de souillures.

Vers la fin du siècle dernier, divers accidents émurent le public et les autorités sanitaires. Une étude générale fut faite de 1898 à 1900 par le Dr. Mosny à la requête du Ministre de la Marine. Il en tira la conclusion que si la grande majorité des parcs se trouvaient installés dans de bonnes conditions, il n'en était pas de même pour certains d'entre eux, nichés dans des ports, dans des fossés de citadelles, dans des estuaires largement pollués. Il aurait fallu supprimer immédiatement ces parcs, mais personne n'osa en prendre la responsabilité et le rapport Mosny alla dormir dans les cartons.

C'est petit à petit, timidement, pourrait-on dire que fut créée une législation sanitaire tendant à assurer la salubrité des eaux nourricières des parcs.

En 1913, convaincu de ce que la prospérité de l'ostréiculture dépendait de la garantie de salubrité offerte au consommateur, quelques commerçants Parisiens instituèrent dans les principaux centres de production un contrôle sanitaire.

Ce contrôle rendit de grands services, mais étant privé, il ne pouvait s'appliquer qu'aux ostréiculteurs de bonne volonté.

Le Congrès des Pêches Maritimes des Sables d'Olonne émettait en 1914 le voeu que fut créé "un organe administratif de surveillance et d'exécution ayant des pouvoirs propres et une responsabilité certaine, pouvant constater et poursuivre les infractions de toute nature, pourvu qu'elles touchent à la salubrité des eaux et des parcs, et surtout ayant l'indépendance nécessaire pour résister aux sollicitations et aux pressions qui jusqu'à présent, ont neutralisé les quelques efforts des pouvoirs publics".

On procéda par étapes:

Les décrets de 1915 et de 1919 exigèrent des enquêtes de salubrité préalables à l'octroi des concessions sur domaine public maritime. Ces enquêtes furent confiées aux Services d'Hygiène, mais ceux-ci n'étaient pas outillés pour assurer le contrôle *général* et *permanent* des établissements de pêche. Ce contrôle fut confié par le Décret du 31 Juillet 1923 sur la salubrité des huîtres à l'Office Scientifique des Pêches Maritimes, Etablissement d'Etat créé en 1918, qui supervisait déjà les certificats de contrôle délivrés par les Associations agréées.

Ce décret de 1923 dont l'application rendit les plus grands services à la santé publique ne s'appliquait en principe qu'aux huîtres et dès le début, son extension aux moules et autres coquillages fût demandée par les autorités sanitaires et la plupart des usagers. En effet, si les épidémies d'origine ostréaire étaient jugulées, certains coquillages pêchés dans des endroits douteux continuaient à nous inquiéter.

Petit à petit, le Service du Contrôle Sanitaire assurait sa situation et obtenait les pouvoirs nécessaires. La loi du 12 Août 1934 habilita les inspecteurs et surveillants ainsi que les Inspecteurs d'Hygiène à dresser procès-verbal des infractions constatées à la règlementation sanitaire applicable aux huîtres et autres coquillages; une décision du Ministre de la Santé prescrivait de joindre l'avis de l'Office des Pêches aux projets d'égoûts prévoyant l'arrivée des

eaux épurées ou non à la mer. Le Décret-Loi du 30 Octobre 1935 décidait la création autour des groupes d'établissements et des grands gisements naturels de périmètres de protection analogues à ceux des sources d'eau minérale et par la création des règlements sanitaires départementaux donnait des moyens d'action contre les collectivités et les individus qui souillent les abords des établissements ostréicoles et menacent leur salubrité.

Enfin quoique promulguée à un moment très défavorable, les inspecteurs étant pour la plupart mobilisés, parut la Charte tant attendue du Contrôle Sanitaire, *le Décret du 20 Août 1939* qui renforce le contrôle des huîtres et l'étend à tous les coquillages. Il a fallu seize années de luttes pour obtenir le contrôle total, mais pendant ce temps, les établissements ostréicoles ont été ou supprimés s'ils étaient dangereux, ou mis à l'abri des pollutions graves, la production a été réglementée et perfectionnée au point de vue sanitaire.

Par contre, en dehors de la zone de production, le contrôle n'existait plus. Or, bien souvent, les accidents causés par les mollusques proviennent des trempages ou arrosages dits de rafraichissement. Il fallait pouvoir réprimer énergiquement ces pratiques, interdire la pêche des gisements insalubres et pouvoir donner aux consommateurs une sécurité totale. Ce fut le but du Décret du 20 Juillet 1939, élaboré au cours de discussions passionnées, promulgué au moment de la déclaration de guerre, mais dont l'application commença grâce à la ténacité du Service du Contrôle dès le début de 1941. Les circonstances exceptionnelles, la crainte des maladies contagieuses permirent une application rigoureuse, une répression sévère et la suppression de parcs d'élevage meurtriers qui défiaient nos efforts depuis de longues années.

Il fallait agir vigoureusement et vite. Les suppressions ont été nombreuses en exécution des deux décrets.

D'autres établissements très nombreux ont été déplacés et réinstallés en eaux saines.

Par endroits, des cités ostréicoles ont été construites et mises à l'abri des pollutions extérieures.

Voici les principales modalités du décret de 1939.

Organisation du Contrôle.

Le contrôle s'applique à tous les coquillages et animaux marins susceptibles d'être mangés crus (oursins, violets, etc.). Il est confié pour sa plus grande part à l'Office Scientifique des Pêches Maritimes en collaboration avec les organismes sanitaires désignés par le Ministre de la Santé. Ce dernier désigne à cet effet les inspecteurs départementaux d'hygiène. L'article 1er du décret prévoit qu'en cas de désaccord, c'est le Conseil Supérieur d'Hygiène Publique de France qui sert d'arbitre. La liaison entre les deux Ministères intéressés: Marine et Santé est assurée par la Commission Supérieure de Salubrité qui donne son avis sur les questions importantes.

Le Service du Contrôle Sanitaire des Coquillages fonctionne sous la haute autorité du Ministre de la Marine Marchande et du Directeur de l'Office des Pêches. Il est dirigé par l'Inspecteur Général qui réside à Paris au siège de l'Office, 59, Avenue Raymond Poincaré.

Quatre Inspecteurs Principaux se partagent la direction des douze inspections régionales dont onze sont chargées de la surveillance des établissements d'expédition et des opérations de pêche et la douzième de la surveillance des manipulations et de la vente à l'intérieur du pays.

Chacune des inspections dispose d'un laboratoire de bactériologie et chimie et de biologie (certains de ces laboratoires sont en cours de création ou de réfection).

Les inspecteurs sont assistés de préparateurs, d'aides de laboratoire et de surveillants. Ces derniers disséminés sur tous les points de la côte et dans les grandes villes de l'intérieur sont actuellement au nombre de cent.

Il y a d'après le décret d'autres personnels chargés d'assurer son application: le personnel de l'Inscription Maritime et de la Surveillance des Pêches, celui de la Santé, les Vétérinaires Sanitaires, les Inspecteurs de la Répression des Fraudes, ceux des Halles et Marchés, la Gendarmerie, les agents commissionnés des syndicats professionnels.

I. Production.

Le littoral est divisé en zones salubres et insalubres.

Tous les gisements habituellement exploités ont été classés au point de vue salubrité. Il en existe actuellement 725.

Le décret a créé des commissions d'appel dites Commissions des Réclamations devant lesquelles les usagers peuvent venir défendre leurs prétentions. Zones et gisements doivent être assainis.

C'est là en effet une question primordiale, car s'il est possible de supprimer des établissements insalubres, s'il est possible d'interdire des créations ou des exploitations dans ces zones, il n'est pas possible de supprimer les gisements naturels. Toutes les précautions que l'on peut prendre, l'épuration même des coquillages ne sont que des pis aller. L'idéal est le principé qui a toujours été admis par le Service du Contrôle Sanitaire: "Produire sain". Il faut donc que chaque fois que cela peut se faire, les causes de contamination soient supprimées et surtout qu'on n'en crée pas de nouvelles. Nous avons pour cela deux armes effectives: les périmètres de protection et les règlements sanitaires départementaux.

Dans les zones insalubres aucune création d'établissements n'est acceptée.

Seuls sont autorisés à expédier ou vendre directement pour la consommation les établissements inscrits sur une liste dénommée "Casier Sanitaire

Coquillier". Y figurent les trois catégories d'établissements d'expédition, d'élevage et d'épuration.

Les établissements non inscrits ne peuvent contenir de produits ayant atteint la taille marchande que sur autorisation spéciale. Celle-ci n'est accordée que s'ils sont situés dans une zone salubre et à la condition de les faire passer par un établissement inscrit avant la livraison à la consommation. Il n'y a donc reparcage que de produits sains.

Le nombre des établissements classés actuellement dépasse 52,000.

Une remarque au sujet de ces chiffres: alors que le nombre des établissements mytilicoles et conchylicoles est sensiblement le même que lors du recensement que j'ai fait à la suite de l'application du décret de 1923, celui des établissements ostréicoles est passé de moins de 25,000 à plus de 42,000.

Il est indéniable que cette augmentation a été favorisé par la création et l'application du Contrôle Sanitaire.

2,453 établissements sont inscrits au Casier Sanitaire.

Les gisements naturels sont soumis à l'examen des commissions de visite chargées de proposer les conditions de pêche, ouverture et fermeture, mode d'exploitation; les gisements salubres et les gisements insalubres ne peuvent être ouverts à la pêche en même temps de façon à éviter le mélange des produits.

Les coquillages pêchés dans les zones insalubres sont livrés à des établissements où ils sont reparqués pendant une durée fixée. Ils voyagent munis d'autorisations de transport sortes d'acquits à caution et ne peuvent en aucun cas être livrés à la consommation avant l'autorisation de l'Inspecteur Sanitaire.

Il est procédé par le Service à des inspections fréquentes qui ont pour but de vérifier l'application des instructions données et de rechercher si des modifications sont intervenues dans les conditions de salubrité ou d'aménagement des établissements inscrits au Casier Sanitaire. Tout établissement inscrit est muni d'un carnet de visite sur lequel sont consignées les observations faites au cours des inspections.

Dans les enquêtes de salubrité faites par l'Office des Pêches l'importance primordiale est donnée à l'enquête topographique et aux constatations sur la tenue des exploitations. Mais on ne néglige pas de se référer au document chimique et surtout bactériologique. Régulièrement et surtout pendant la durée de la saison ostréicole, les laboratoires de l'Office procèdent à des examens d'eau et d'huîtres multipliées.

Au point de vue chimique, on se borne ordinairement au dosage des chlorures, qui mesure l'importance des apports d'eau douce et permet de mieux interpréter les résultats de l'examen bactériologique. Celui-ci consiste, d'une façon courante, dans la recherche et la numération du bacille coli et dans la constatation de l'absence de bactéries putrides. S'il est nécessaire, les recherches sont poussées plus loin.

On demande à ces analyses de confirmer ou d'infirmer l'opinion qu'on s'est faite par une prospection attentive des lieux, de mesurer en telles ou telles circonstances le degré d'une pollution reconnue; de vérifier le maintien des conditions de salubrité, sur lesquelles un parc fut classé. Les résultats des analyses sont conservés au dossier de l'établissement de façon à ce que nous puissons vérifier non seulement les résultats, mais les variations qui peuvent se produire dans ces résultats. Ces variations sont souvent plus importantes que les résultats eux-mêmes, car elles peuvent indiquer la présence de pollutions inattendues.

Il faut ajouter que l'action du Service du Contrôle Sanitaire est essentiellement préventive. Elle consiste à rechercher les risques de contamination des coquillages, puis à les faire disparaître ou à les neutraliser, en quelque sorte, par des moyens de défense appropriés. A cet objet suffit généralement la détermination d'un indice de pollution convenablement choisi. Et comme tous les accidents infectieux d'origine coquillière sont causés par des bactéries intestinales, le bacille coli est le test de choix.

La recherche et l'évaluation numérique du *B. coli* sont faites par culture en bouillon de peptone salé et phéniqué, puis caractérisation de l'indol, suivant une technique connue, employée au service de surveillance des eaux d'alimentation de la ville de Paris. Pour les huîtres, comme la quantité de glycogène que renferme leur foie contrarierait la production d'indol, on procède après une première culture et un repiquage en même milieu. Une expérience pratique vieille déjà de plus de vingt ans permet de dire que cette méthode, d'éxécution simple, relativement rapide, s'applique bien au cas que nous avons à traiter. Elle n'exclut d'ailleurs pas l'emploi d'autres méthodes s'il y a lieu.

II. Transport.

Les produits destinés à la consommation ne peuvent être transportés *en vrac:* les coquillages doivent être arrimés dans des emballages rigides, avec des couvercles attachés fortement pour éviter toute contamination dans le transport et assurer leur parfaite conservation.

Les principaux emballages actuellement admis pour les huîtres sont:

les paniers d'osier, les paniers en bois déroulé, les caissettes en bois léger de différentes tailles.

Les moules sont le plus souvent expédiées en sacs, parfois en caisses. Nous préconissons l'emploi du grand mannequin d'osier déjà utilisé par certains mytiliculteurs soucieux de la qualité de leur marchandise.

La plupart des coquillages sont expédiés en sacs.

Il faut que les sacs soient propres et ne soient jamais déposés dans des endroits souillés.

Le transport derrière les autobus (échappement, éclaboussures etc.) ne peut être admis.

Tous les colis doivent être munis d'une étiquette de salubrité portant le numéro du certificat de l'établissement expéditeur et timbrée à la date du départ du lieu d'expédition. Ces étiquettes sont délivrées par l'Inspecteur Régional qui fixe aux usagers les conditions de cette délivrance.

Il existe actuellement pour les expéditeurs ou éleveurs des étiquettes destinées aux huîtres (B et D) et des étiquettes destinées à couvrir les colis de moules et coquillages (C). Les pêcheurs reçoivent des étiquettes spéciales (E).

Les réexpéditeurs qui n'appartiennent pas aux catégories ci-dessus employent pour les huîtres l'étiquette F et pour les autres coquillages l'étiquette G.

Est considéré comme réexpéditeur tout commerçant qui expédie à nouveau ou fractionne en plusieurs colis un colis d'huîtres, de moules ou de coquillages provenant de la côte. Chaque nouveau colis doit être muni de l'étiquette de réexpédition.

Les réexpéditeurs doivent posséder des locaux convenablement aménagés pour leur commerce. Ces locaux doivent être peints à hauteur d'appui, cimentés, munis de postes d'eau et de clayonnages.

Ainsi est réalisé le voeu émis à Rochefort en 1934 par l'Assemblée Française de Médecine Générale:

"... Que les différentes manipulations auxquelles l'huître peut être soumise par les différents commerçants qui, après l'avoir reçue de l'ostréiculteur, le vendent au détail aux consommateurs soient l'objet d'une surveillance officielle afin d'éviter toute contamination".

Les surveillants de l'intérieur placés sous l'autorité de l'Inspecteur Régional de Paris ou des inspecteurs principaux contrôlent non seulement les manipulations, mais l'origine, la fraicheur et la qualité des produits. Ce contrôle se superpose à celui exercé par les vétérinaires, les inspecteurs des Halles et marchés, les fonctionnaires locaux, etc.

Les pêcheurs sont également immatriculés au Service. Ceux d'entre eux qui sont classés comme pêcheurs-expéditeurs doivent posséder des installations appropriées à l'importance de leur commerce. Les pêcheurs emploient une étiquette spéciale; l'étiquette E qui porte en surimpression l'ancre et les harpons de l'Office des Pêches. Il existe enfin une étiquette spéciale pour l'emploi des échantillons commerciaux, c'est l'étiquette I. Les produits ainsi expédiés ne peuvent être livrés à la consommation.

Le prêt ou la cession des étiquettes ne peuvent en aucun cas être admis sous peine de conséquences graves. En effet, c'est l'acheteur de l'étiquette le seul ayant-droit, qui serait tenu comme responsable en cas d'accident. Il perdrait son certificat de salubrité sans préjudice des autres peines qui, pourraient lui être infligées par les Tribunaux ou par l'Administration. Les usagers doivent pouvoir justifier de l'emploi des étiquettes qui leur ont été délivrées. Ces étiquettes portent d'ailleurs un numéro spécial qui est conservé avec leur numéro de salubrité par les dépositaires chargés de leur délivrer.

III. Vente.

Chaque colis doit être muni d'une étiquette qu'il soit exposé à la vente ou en cours de transport. L'étiquette n'est valable qu'une fois et elle ne couvre que la marchandise emballée dans le colis désigné.

Il est interdit d'entreposer les coquillages par immersion même si l'endroit est situé en zone salubre.

L'importation des coquillages étrangers est soumise à une règlementation spéciale. S'ils sont immergés dans nos eaux, ils rentrent en outre dans la règle commune.

Aucun envoi à l'exportation ne peut être admis à voyager sans pièces de salubrité. L'autorisation H ne peut être accordée que pour le reparcage dans les pays où l'équivalence est reconnue. Elle doit être visée par l'Inspecteur Général.

IV. Sanctions.

Les infractions aux dispositions du Décret du 20 Août 1939 peuvent entrainer les sanctions suivantes:

1° Suspension du certificat de salubrité pour une durée de un à six mois.

2° Radiation de la liste.

Ces sanctions sont prises par le Ministre de la Marine Marchande sur la proposition du Directeur de l'Office des Pêches. En ce qui concerne la radiation, la Commission des Réclamations peut intervenir. En cas d'urgence, le certificat est suspendu à titre provisoire par le Directeur de l'Office. Cette décision est soumise à la ratification du Ministre. Les mêmes sanctions peuvent être prises contre les réexpéditeurs et les pêcheurs.

Les procès-verbaux dressés par les fonctionnaires et agents habilités à cet effet sont transmis aux autorités judiciaires. Les infractions sont punies des peines de simple police ou le cas échéant des peines plus graves prévues par les lois en vigueur (amendes, peines de prison et retrait à la concession ou de droit de pêche).

Les coquillages provenant des zones insalubres, ou non couverts par les étiquettes réglementaires, sont saisie et détruits.

Somme toute, les coquillages qui sont actuellement livrés au public proviennent soit d'établissements situés dans des zones reconnues salubres par les Services de la Santé et du Contrôle Sanitaire de l'Office des Pêches, soit directement de gisements reconnus salubres.

Les coquillages provenant de gisements non reconnus salubres sont épurés pendant le temps né-

cessaire dans des établissements salubres sous surveillance spéciale. Il n'existe plus d'établissements d'expédition dans les zones insalubres. Le Décret du 20 Août 1939 marque un réel progrès en ce qui concerne la salubrité des coquillages et l'action conjuguée des Services du Contrôle Sanitaire et de la Santé Publique produit les meilleurs effets.

Depuis son application, en France, il n'est plus question d'épidémies de fièvres typhoïdes d'origine coquillière et l'étiquette de salubrité donne au consommateur une garantie efficace. Nombreux sont les pays étrangers qui ont adopté notre contrôle en acceptant l'étiquette Française.

Le savant spécialiste Américain R. H. Fiedler a pu écrire que "les huîtres et autres coquillages sont actuellement les aliments les plus sévèrement contrôlés de la production à la consommation. C'est", a-t-il ajouté, "un aliment qui peut être mangé cru ou cuit et un de seuls d'origine animale qui peut être absorbé entièrement."

Référence.

L. Lambert. "Les Coquillages Comestibles (Huîtres, Moules, Coquillages variés)." Collection "Que sais-je?", 2° Partie, Presses Universitaires de France, Paris, 1950.

10.

Bacteriological Control of Zealand Oysters and Mussels.

By

A. Grijns

The control was established in 1906 after and in consequence of the disastrous banquets at Southampton and Winchester (England) in September 1902, which clearly showed the danger of the consumption of polluted shellfish and which caused a serious oyster scare in England and on the Continent. The Dutch Minister of Finance, fearing a severe decline of the proceeds of the domain in the Zealand streams leased to the oyster- and mussel-growers, consulted a committee of wellknown Dutch hygienists, who advised him to establish a bacteriological control of the Zealand shellfish.

The Board of Fisheries on the Zealand streams, as the governmental body, was charged with the carrying out of this control. A bacteriologist was appointed as chief of this special service.

The bacteriological examination of numerous samples of sea water, mud and shellfish, taken under different circumstances of tidal movements, weather, wind and temperature, has made it possible to classify all oyster and mussel plots on the beds and all oyster basins, as clean or polluted. Oysters and mussels from clean areas are despatched with a certificate of cleanliness; the polluted shellfish is dredged up and relaid in clean areas. After a period of quarantine of a fortnight, which starts when the last shipload has been relaid, these oysters and mussels are also despatched with a certificate. Despatch without a certificate is forbidden by law.

The oyster- and mussel-growers who request the right to use certificates, have to enter into a contract with the Board of Fisheries containing all regulations for the contracting party, who has to pay a maximum fine of £ 100 for every infringement without recourse to any court of law. Moreover there remain to be mentioned the regulations of the local authorities at Yerseke, Tholen and Bruinisse protecting the cleanliness of the oyster basins in those places and preventing people, who have cases of typhoid fever in their family or who are known as carriers, from working in the oyster- or mussel industry.

It is obvious that all these regulations would be of no use without a strict control, which is carried out by 33 officials of the Board of Fisheries aboard 8 motor boats and ashore at the places mentioned above. It is a great advantage that the whole culture is concentrated in a rather small area.

The effectiveness of the whole system is demonstrated by the fact that within a period of 43 years no cases of typhoid fever caused by the consumption of Zealand oysters or mussels have been registered.

The methods used for the bacteriological examination may be described as follows.

The samples of oysters and mussels are externally cleansed with a hard brush under the tap. The oysters or mussels are opened with a sterile knife, while the shell is held in a sterile towel. The shell liquor is put in a sterile jar. The body is minced up in the shell. The body liquor is pressed out with the knife and added to the shell liquor in the jar. The liquor of 6—10 oysters or mussels is pooled and shaken.

From this mixture a dilution series of 5×1 ml., $5 \times 0{\cdot}1$ ml. and $5 \times 0{\cdot}01$ ml. is made in lactose-broth tubes provided with inverted Durham tubes, which series are incubated for 48 hours at 37° C. The fermentation in the positive tubes is confirmed by the transfer of a loopful to brilliant green lactose bile broth, which is incubated for 48 hours at 37°, and to modified Eijkman lactose medium, which is incubated for 48 hours at 45·5°.

The number of bacteria of the coliform-group is expressed as the most probable number (M.P.N.) per 100 ml. liquor and determined by the tables of Hoskins 1).

The bacteriological method given above has been developed from the Recommended Methods of Procedure of the American Standard Methods Committee for the Examination of Shellfish 2); the preparation of samples for examination is different.

A second method used is that of the Fishmongers' Company in London 3), especially for oysters and mussels exported to England. Ten oysters or mussels

are opened with a sterile knife, minced up in the shell and mixed with the shell liquor; 0·2 resp. 0·1 ml. of the mixture is inoculated into MacConkey tubes with phenolred as an indicator. After incubating for 24 hours at 37° the number of positive tubes (formation of acid and plenty of gas) is recorded and the percentage purity calculated (0 positive = 100% clean; 10 positive = 0% clean), Shellfish giving the result 100—60% clean may be sold directly, 50—40% clean need a further analysis, 30—0% clean is condemned.

The Zealand standard of purity for shellfish has always been the absence of coliforms in 0·1 ml. of the mixture of body and shell liquor. During the season 1947/48 the purity of the Zealand oysters was on an average 147 (expressed in M.P.N. per 100 ml.) and of the Zealand mussels 236. The average percentage purity (Fishmonger's Company test) during the season 1948/49 was for oysters 91% clean and for mussels 89·4% clean.

The faults inherent in the methods for bacteriological examination of shellfish used hitherto have been clearly demonstrated by Dodgson4) and recently by Clegg and Sherwood5). The new method proposed by the latter seems to be an important improvement. I regret I have not had the opportunity to try this method as a routine test as I was not able to obtain a reliable water bath. I hope to do so in the future.

I would like to mention here the development of a controversy about the system used in France and Zealand, i. e., the production of clean shellfish from clean areas and the purification of polluted shellfish in clean areas during a period of quarantine, and the purification system of Dodgson, i. e., the purification of all shellfish in closed basins by means of chlorinated sea water.

Although Dodgson admits in his Report on Mussel Purification (l. c., p. 108) that the impression gained after a thorough inspection of the mussel beds in south Holland (i. e., Zealand) was entirely favourable in respect of the absence of pollution at the source, he insists nevertheless (l. c., p. 109) that all imported mussels shall be subjected to a purification treatment in England before being put on the market for human consumption.

Dodgson's objection against our system is the impossibility of preventing incidental pollutions on the plots and in the basins and "en route" to England. As far as incidental pollution in Zealand is concerned our experience during a period of 43 years demonstrates that Dodgson's objections are exaggerated; in regard to the pollution en route, purified and non-purified shellfish are equally susceptible; several samples of purified shellfish have been condemned in the London market probably on account of pollution en route.

I admit the safeness of the purification treatment; nevertheless I have an aesthetic objection against it, which concerns the use of polluted sea water made bacteriologically clean by chlorination and freed from insoluble filth by sedimentation, but which still contains all soluble sewage materials such as urine, etc. From this point of view the purification treatment does not answer the requirements of Dodgson himself, when he says (l. c., p. 88) "As pointed out elsewhere, it is desirable, on aesthetic grounds, that mussels, however cooked, should have been freed from filth, apart altogether from the question of presence of living bacteria".

Everybody will admit that it must be much more attractive to eat oysters and mussels taken from clean sea water than from a chlorinated mixture of sea water and sewage. The situation in England makes it nearly impossible to find a spot where the sea water is free from pollution, but I think it is unfair to exclude the non-purified shellfish of countries which are more lucky in regard to pollution.

As a result of the controversy mentioned above the Medical Officer of Health at Sheffield (England) has forbidden non-purified shellfish to be sold in that town.

A standard of purity, as proposed by Clegg and Sherwood (l. c., p. 520), which might be too high for non-purified shellfish, would render impossible the marketing in England of shellfish which have not passed a purification plant.

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11.

Investigations on Shell-Disease in the Oyster, *Ostrea edulis* L.

By

P. Korringa

Introduction.

A sudden and catastrophic outbreak of shell-disease was observed in the Dutch oyster centre, the Oosterschelde, in the years following 1930. This disease is characterized by the appearance of bottle-green and orange-brown rubber-like spots and warts on the shell's inner surfaces. In more severe cases these spots are accompanied by serious deformations of the shell's edges and hinge part and by an alarming mortality, especially among the young oysters. It was Hoek (1902) who was the first to inform us about the occurrence of shell-disease in Dutch waters. The percentage of oysters affected in his day was so low, however, that he did not worry about it.

Preliminary investigations carried out by Havinga (1931) demonstrated the severe character of the 1930 outbreak and indicated the complexity of the entire problem. The oystermen's hope that the disease would disappear as suddenly and mysteriously as it had come, vanished into thin air, and eventually they were faced with a serious crisis in the entire Dutch oyster industry. The present author was charged with investigating shell-disease and started his work in the Bergen-op-Zoom Shellfish Laboratory in the year 1937. Only part of the work could be carried through in the laboratory, however. Field investigations carried out under natural conditions had to give the answer to the multitude of questions which soon arose. In this work the technical advice and skilful assistance rendered by the able officers of the Zealand Fishery Police have been invaluable. Only a brief account can be given here of the main results of the investigations. We hope to publish the acquired knowledge in full in the near future.

Laboratory Investigations.

Laboratory investigations revealed that the green rubber-like spots and warts in the shell's interior could not be explained by the oyster being locally incapable of secreting the normal hard shell-layers next to the conchyolin, interwoven with calcareous matter in any mollusk shell. Nor by the calcareous substance having been dissolved after its deposition. The green warts could only be accounted for by assuming a local abnormally intense secretion of conchyolin. The mollusk shell itself being inanimate, investigations to clear up the cause of abnormal shell secretion should focus on the living tissues of the oyster and notably on the mantle epithelium which is in charge of secreting the shell. Carrying through histological observations on healthy and diseased oysters, my serial sections showed me that the mantle epithelium consists of low cells, nearly cubical in section, interspersed with small unicellular glands. In one place, however, opposite the ligament which connects the valves, very high and slender cells were found to compose the mantle epithelium. The oyster's ligament, consisting of a tough rubber-like material, is apparently secreted in successive layers by those high slender cells, while the low cells with the interposed glands are in charge of the secretion of the calcareous part of the shell.

Opposite the green warts and spots in diseased oysters I found a mantle tissue consisting of the same high and slender cells which secrete the ligament in healthy oysters. For some still obscure reason diseased oysters proceed to secrete normal green rubber-like ligament material on abnormal places in the shell and in abnormal quantities.

Death appeared to be likely in cases where the diseased spot was or became situated under the muscle scar. Then, often large parts of the muscle tissue appeared to be replaced by the typical diseased mantle tissue, thus dangerously interfering with the oyster's shell movements. Where the disease happened to be located along the shell's edges, normal shell growth was impossible. Many oysters died, others were seriously disfigured and could never grow to a normal marketable oyster.

Further, it could be demonstrated that the formation of the green spots and warts was a symptom of an advanced phase of shell-disease. Earlier symptoms were cloud-like spots of a chalky white colour, contrasting with the pearly lustre of the normal shell, and not to be confounded with the so-called chalky deposits, which are thick and porous. The white clouds

in the shell's interior proved to be proceeded, in their turn, by tiny specks of a chalky white colour of the size of a pin's head. These tiny white specks, the first symptom of shell-disease to be observed with the naked eye, could be found in oysters of different age-groups. Even oyster spat, a few months old, often appeared to show these specks and were thus marked as diseased in their early youth.

Field Work.

Investigations to clear up the epidemiology of the disease could only be carried out in the field. It was considered important to learn where and when the disease spreads and what is its course under different external conditions.

The Place Factor.

To find out which part of the oyster beds were the heaviest infested by shell-disease, and whether certain parts of the Dutch beds happened to be free of it, a great number of samples of spat have been examined. After having found that the number of white specks shows no further increase after about 1st October, I collected samples in October and November and examined them in the laboratory, noting the percentage of the spat showing white specks and recording the number of specks per shell. After these data had been depicted on a map of the oyster district, it could easily be demonstrated that shell-disease is not evenly distributed. On the contrary, pronounced niduses, showing high figures, could be located in several places. Elsewhere shell-disease appeared to be of little or no importance. It is a very characteristic feature that each nidus gradually blends into more healthy areas. No sharp limitations are ever observed. Such maps, showing the distribution of shell-disease in the spat, have been prepared for several years. There appeared to be a great difference in intensity of attack from year to year, but each nidus, as well as the healthy sites, appeared to occupy a fixed place on the map.

The Time Factor.

After having cleared up the influence of the place factor, I tried to find out the effect of the time factor. Is the oyster liable to infection throughout its life? Under what external conditions does the disease attack new victims? What is the fate of oysters fallen victim to the disease?

Oyster spat appears to be very sensitive to shell disease. Further, oysters one year old are an easy prey. Healthy oysters of two years and older appear to be quite resistant and suffer little, as a rule, even when exposed in a nidus of disease. Placing trays with young oysters in a nidus of disease and examining samples weekly proved to be an excellent way of following the events. It soon became evident that shell disease spreads in the summer season, often during a few weeks only. In the remainder of the year the symptoms may aggravate or temporarily come to a standstill, but no new victims are made.

After many years of experiments and observations I was in a position to discover the uniformity in this process. It became clear that shell-disease only spreads at water temperatures above 19° C., the higher the temperature the more vigorous the attack. Curiously enough a temperature of 19° C. or higher needs to be maintained for some 10 days before shell-disease makes its appearance. If the temperature drops before this period has elapsed, nothing happens. This close correlation between water temperature and attack of shell-disease explains the great difference in disease from year to year. In the meantime it offers the possibility of predicting a forthcoming attack.

As the appearance of white specks in the shell has been used as an indicator of the spreading of shell-disease, we wonder whether or not the first phase of the attack, not to be observed with the naked eye, could be detected much earlier I carried through extensive transplantation schemes with young oysters, regularly interchanging batches from healthy and diseased places, and found out that the period of incubation is very short. The white specks appear within a few days after the first attack has taken place. Therefore the appearance of white specks is an adequate indicator of the appearance of shell-disease, and their number is a measure of its intensity.

What is the fate of oyster fallen victim to the disease, when kept under different external conditions? To investigate this point, diseased oysters have been kept under observation for prolonged periods, up to two years. I used oysters of different age-groups and placed them under natural conditions in several well selected stations. From those investigations it became evident that nothing happens during the winter season. From October till the end of May the symptoms remained constant. In the warmer season, on the other hand, the disease may rapidly become worse. White specks increase in numbers, congregate into groups of specks, develop into white clouds in the centre of which green rubber-like material will be laid down in due time. The green spots grow and unite with others, ultimately blocking the edge of the shell, thus making shell growth impossible, or shift under the adductor muscle, which development may prove to be fatal. As long as shell growth takes place, the symptoms of the disease increase. In oysters showing apparently harmless white specks in spring, green spots and warts may appear as early as June, and death may follow in July or August. Light cases develop malformations of the shell only. Spat heavily attacked by shell-disease may die off within a few months. Spat showing a light attack only usually survive, but develop into oysters with badly disfigured hinge parts. If one-year-old oysters are severely attacked, they all die.

It is of no use to transport diseased oysters into a healthy area. As soon as shell growth begins, the symptoms of the disease increase, irrespective of where the oysters are grown.

Different Methods of Oyster Culture.

It was of the greatest practical importance to find out whether or not spat produced by different methods of oyster culture was equally subject to shell-disease. I compared spat on tile-collectors with that on mussel shells and with that attached on the most natural collector, the new shoots of older oysters. I found that the percentage of the spat diseased depended only on the place where I sampled and not on the kind of collector used. Even spat kept well above the bottom in wire-covered trays showed the same percentage of diseased as those lying on the bottom nearby. Spat kept within the enclosure of a flood basin and therefore never exposed at low tide, showed the same percentage of victims as spat kept immediately outside that basin, and therefore exposed for several hours every day.

This all led to the conclusion that it is the place where the spat is kept during the spreading of the disease in the summer season and not the method of oyster culture which determines to what degree it will be liable to shell disease.

This conclusion does not imply, however, that the method of oyster culture is of no importance whatever in this connection. Sloping banks along the dikes, the healthiest areas west of Yerseke, are best suited for the placing of tile-collectors, but not for the scattering of mussel shells. The oyster farmers, kept informed about the results of our investigations, soon proceeded to place all their tile-collectors in the area indicated by us as free of disease, though this entailed greater expense. The result has been that the spat produced with tiles is, to a high degree, free of shell-disease and therefore much in demand. Further, the oyster farmers stopped scattering mussel shells on the grounds indicated as a nidus of shell disease. Much spat is still produced, however, on beds at close quarters to the niduses, with the result that its quality is found to be unsatisfactory after warm summers, characterized by a severe attack of shell-disease.

The True Nature of the Disease.

Though the knowledge acquired on the influence of place, time, and method, of oyster culture proved to be of the greatest practical importance and led to instructions to evade an attack of shell disease, we could not be satisfied with abandoning the nidus of shell disease. We wanted to find out the cause of this disease and of its sudden deterioration in the years following 1930.

Generally speaking, there are different kinds of disease. Some are caused by infection, others by a deficiency in certain constituents in the food. Further there are diseases caused by extreme deviations from the normal environmental conditions and still other diseases are ascribed to degeneration after prolonged inbreeding.

The characteristics of shell-disease, already discussed, allow us to deduce that shell-disease in the oyster should be reckoned among the contagious diseases. The short period of its distribution, its regular appearance from year to year, its correlation with water temperature, the occurrence of marked niduses next to the observation of favourable growth and fattening in non-diseased oysters in the same waters, all point in this direction.

In my pursuit of the cause of this disease I tried to find out whether a parasitic organism could be detected in the diseased mantle epithelium opposite the green spots in the shell. No fungus, bacterium or protozoan could be demonstrated to occur regularly in the diseased tissues. The curious and different patterns of green spots in the individual oysters could hardly be explained by assuming a virus as the cause of the disease. Efforts to isolate an infectious organism from the diseased tissues by the approved laboratory techniques failed to yield positive results and so did my efforts to infect healthy oysters by injecting preparations of diseased mantle tissue.

Though the diseased tissue opposite the green spots and warts can easily be recognized under the microscope and often even with the naked eye, I failed to recognize any aberrant feature in the mantle epithelium opposite the white specks, which always precede the appearance of green spots in diseased oysters. After many vain attemps I decided to follow other paths in investigating this particular phase in shell disease. If the white specks in the shell could be ascribed to slight aberrations in the shell secreting mantle tissue, though I failed to detect such aberrations in my serial sections, they should be reproduced in the same characteristic patterns if that particular piece of the shell had been taken away. I carried through this experiment and was surprised to find that the shell layers, which had been secreted to replace the pieces of shell taken away from the edge, were always free of white specks and other symptoms of disease. Then I started another experiment, in which a piece of shell, bearing white specks, was carefully implanted in the shell of a healthy oyster. After new growth had been put on, the layers deposited on the implantate appeared to suffer from shell-disease, while the remainder of the shell was as healthy as before.

These experiments proved that the disease, in its early development, had its seat in the shell itself and that aberration of the living mantle tissue is a feature of a later phase.

Further, I found out that shells of oysters living in a nidus of shell-disease are not attacked over their entire surface. Only recent new growth, and other parts of the shell which happen to be very thin, such as the shells of young spat, can be invaded by the white specks. Thicker parts of the shell cannot be attacked. Moreover, parts of the shell which are not freely accessible from the outside, like the undersurface of shells of spat settled on tile-collectors, are always free of shell-disease, even when the shells are very thin.

This all eventually led to the conclusion that the shell is attacked from the outside. The infective organ-

ism must have the power to perforate thin parts of the shell before it can start exercising its fatal influence on the living tissues. This influence first causes only minor aberrations in shell secretion, resulting in tiny white specks on the inside of the shell. Later its action brings about irreversible changes in the living mantle tissue, ultimately resulting in serious deformations of the shell or even in death.

It seems incredible that a bacterium or a virus is able to perforate oyster shells, which only a fungus can do. Using the technique of the geologist, I produced thin slides of oyster shells. Investigating early phases of shell-disease, I found that every white speck of pin-head size has a narrow hole in its centre, in which hole a fungus thread can be found making its way towards the shell's interior. After its arrival there it branches abundantly and obviously starts irritating the living tissues. This first leads to minor aberrations, like the white clouds, but ultimately to serious defects and even death.

The entire process resembles strikingly the events during the formation of plant galls. There, too, the secretion of a tiny organism, an egg, a maggot or a fungus, leads to aberrations in the normal development of the growing plant tissues, and ultimately leads to complicated deformations, constructed of the plant's normal cells, but produced in abnormal places and in abnormal quantities.

Characteristic Features of a Nidus of Shell-Disease.

The next problem was to find out why the fungus is so abundant in the nidus of disease, and not elsewhere. The gradual transition from a nidus of disease to a healthy area, and the fact that oysters kept on trays suffered as much as those lying on the bottom, led to the conclusion that shell-disease is water-borne.

I assume that large numbers of spores of the fungus responsible for shell-disease are produced in each nidus, attacking all the oysters there and spreading gradually to more healthy areas, carried by the tidal currents. The further away from the nidus, the more the spores become diluted, hence the smaller and smaller number of white specks in the oysters and a larger and larger percentage of oysters entirely free from specks, as we enter a healthy area.

A closer investigation of a nidus of disease led us to the remarkable conclusion that the number of diseased and dead oysters, which could be considered to represent the source of each new infection, is often very limited. Even on several of the most dangerous spots diseased or dead oysters were totally absent. The only constant feature of each nidus of shell disease appeared to be a high percentage of old shells in the superficial bottom layers. Those old shells, most of them cockle shells (*Cardium edule*), were brought there in earlier years as collectors but, owing to fouling, no longer served for this purpose. Maps depicting the quantity of shells in superficial bottom layers resemble so closely the maps depicting the distribution of shell-disease that they are virtually identical.

The colour of the old shells is green, due to perforating algae. Next to the algae the old shells appeared to lodge an abundance of fungus threads. The old shells being themselves free of organic matter, the fungus probably gets its food from the perforating algae.

Is it too bold to assume that the spores infecting the oysters are produced by the fungus living in the old shells and reproducing in the warmest period of the summer season? I was in a position to demonstrate that this is really what happens! In a season characterized by a profuse spatfall some spat could be found on the old fouled green shells. This spat was invariably in a very bad state, and suffered from an immediate attack of the fungus living inside the old shells. Apparently it is very easy for the fungus to perforate the thin undermost shell of the newly settled spat. This undermost shell, which cannot be reached by the spores, is always free of disease in spat on tiles and on newly scattered shells. This fungus attack even takes place at water temperatures below 19° C., during which no spores are produced, so that spat on tiles and newly scattered shells remain healthy.

Conclusion.

The picture was now complete. The fungus living in the old green shells produces spores on a very great scale in the warmest part of the summer season. Those spores are carried about by the water currents. The germinating spores are able to perforate the thin young growth of oyster shells and to start a parasitic life there, with all the disagreable consequences known to us as shell-disease. Other spores find their way to old shells and start a more innocuous life in co-operation with perforating algae.

This makes clear why, in our experiments, a limited number of diseased shells and limited quantities of old green cockle shells failed to infect healthy young oysters kept on the same tray in a healthy area. Obviously, the dilution of the spores by the water currents was far too great under such conditions. Further, it is now easily understood why it proved to be useless to clean a limited space in a nidus of shell-disease from old shells, for spores are amply supplied from the surrounding grounds.

An explanation could be found for the remarkable fact that shell-disease spread so rapidly and fatally in the years following 1930. Our first Government Fisheries Biologist, Dr. P. P. C. Hoek, described shell-disease in his 1902 report and stated that it occurred only in a very limited percentage of the oysters at that time. Between 1920 and 1930 enormous quantities of old cockle shells had been scattered as collectors in a foolish effort to raise the production of young oysters. Instead of about 5,000 m.³ shells, 40,000 to 50,000 m.³ were used annually. This gave the fungus its chance to proliferate enormously. Hence the number of spores produced annually soon rose to

an alarming and fatal level, and shell-disease, once obscure, became rife.

I believe that shell-disease occurs on many of the European oyster beds. Most probably it is identical with the French "Maladie-du-pied". I repeatedly observed its victims in Brittany (France), both on old natural oyster beds and on bottoms in use by the French oystermen. In Brittany too, severe infections can be located in the vicinity of large quantities of old shells, partly kept there as a method of conservation. In Brittany too, warm summers produce a great activity of the shell-disease fungus. In the spring of 1949 many lots of French oysters for relaying had to be refused by the Dutch buyers because a too high percentage of these oysters appeared to suffer from shell-disease, as a result of the warm summer of 1947.

Methods of Control.

Our knowledge of shell-disease, gathered in the course of many years, eventually led to appropriate methods of control.

Our earliest advice was to evade the niduses of disease and to concentrate spat production in the area indicated as healthy. Ultimately we could encourage the wholesale cleaning of old abandoned beds to get rid of the old green shells, which produce the fatal spores every summer. The united oyster farmers started to clean the unproductive abandoned beds at their own expense. We try now to keep the oyster beds in perfect condition and to avoid accumulation of shells by regulating the use of mussel shells as collectors. The use of the resistant cockle shells as cultch is now prohibited.

The most spectacular method of control, giving almost immediate success and recently applied on a very large scale by our oyster farmers, is a disinfection of the diseased oysters. After extensive experiments it appeared to be possible to kill the fungus within the oyster shell by bathing the oyster for an hour in a toxic solution using an organic salt of mercury. The oyster closes its shells tightly in this solution and is not injured at all, but the fungus is killed within the shell because the toxic product enters through the hole the fungus drilled in entering the shell. This method can only be applied as long as the disease is in its early developmental stage. As soon as green rubber-like spots make their appearance in the shell, indicating that the living tissues have been changed irreversibly, chemical control is no longer possible. Disinfection has been practiced on a very large scale and with great success after the heavy attack of shell disease in the warm summer of 1947. We estimate that about 15,000,000 one-year-old oysters have been saved from an almost certain death that year.

Shell disease, once a serious menace to the Dutch oyster culture, threatening to destroy this important industry, had its mysteries revealed bit by bit in the course of our investigations. Difficulties arose from the necessity of carrying out all the crucial experiments in the field and checking the results at the end of each summer season. A new set of experiments could not be started before the onset of growth in the next spring. It goes without saying that war difficulties during the German occupation hampered our work in no small way. We were short of adequately equipped boats and fuel as a result of German restrictions in the coastal area, and often exposed to the dangers of war.

We know now how to combat this disease which caused such heavy losses and reduced so much the quality of our oysters. Oysters recently attacked are saved by applying disinfection. We trust that the wholesale cleaning of the niduses of disease will ultimately relegate this disease to the modest place it formerly occupied.

Summary.

Shell-disease in the oyster (*Ostrea edulis* L.), characterized by the occurrence of green rubber-like spots and warts in the shell's interior, next to serious shell malformations and heavy mortality, broke out in the years following 1930 in the Dutch centre of oyster culture, the Oosterschelde. This disease seriously menaced the Dutch oyster culture and threatened it with extinction. Investigations carried through in the field revealed bit by bit the secrets of this once so mysterious disease. A fungus thriving abundantly in old green cockle shells, used in tremendous quantities as cultch in the years 1920—1930 on now abandoned bottoms proved to be the source of infection. The spores of the fungus are distributed by water currents and are able to perforate thin, newly made parts of the oyster's shell. Irritation of the oyster's living tissues ultimately leads to irreversible changes, deformations and death. Uniformities in the spreading of the disease have been traced and could be used to find out how to evade infection, where and when to expect it, and in what intensity.

Wholesale cleaning away of old useless shells of *Cardium* and *Crepidula*, next to disinfecting young oysters recently attacked, in which a solution of an organic salt of mercury is used, are the methods of control devised by us and adopted by the Dutch oyster farmers.

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12.

Crepidula fornicata as an Oyster-Pest.

By

P. Korringa

Introduction.

Since man developed a commercial interest in marine mollusks, among which the oyster can be reckoned as the most valuable species, an interest starting with fishing on natural beds and finally leading to a real cultivation in several countries, he considered any creature counteracting him in his efforts as a pest. We reckon among the oyster-pests not only creatures feeding on oysters, such as starfishes, drills, and some fishes, but also some little-known parasitic creatures living inside the intact oysters, and any organism which smothers oysters or grows on the oyster's shell in such quantities that the latter becomes liable to drift away on the currents. Though young oysters easily suffer from smothering by luxuriant growth of organisms which settle down on the same piece of substratum as they do (e. g., ascidians, Bryozoa, sponges and Algae), larger oysters may suffer too, especially from seaweeds developing too abundantly on their shells or on the beds. Thus, in Holland, *Dictyota dichotoma* and *Chorda filum* were reckoned among the oyster-pests in some past years, but are considered just harmless cohabitants now. Other so far apparently harmless creatures may for no obvious reason suddenly turn into oyster-pests, as did in Holland the seaweed *Codium fragile* (Sur.) Hariot which recently started to grow in such quantities on the oysters' shells that many oysters were carried away with the tidal currents.

The oyster farmer, like the agriculturist and the horticulturist, cannot be satisfied with the knowledge of the existence of a general biological balance in nature, which sees to it that organisms which try to "escape" are in due time brought back to normal occurrence by their enemies and diseases. The oystermen cannot wait for the balance of nature to be restored, but want to avoid or counteract oyster-pests wherever and whenever possible.

Though native creatures may be permanently an oyster-pest or may suddenly and often temporarily turn into one, the greatest danger may threaten when foreign species are introduced from abroad. As a rule such species cannot thrive under the new conditions, but if the new environment happens to suit them, the absence of their natural enemies and diseases may lead to a reproduction at an astronomical rate and to the upsetting of the natural balance in an entire area. The introduction of rabbits and the prickly pear (Opuntia) in Australia, of goats in New Zealand and on many an Oceanic isle, of the Colorado-beetle (*Leptinotarsa decemlineata*) and the Chinese crab (*Eriocheir sinensis*) in Europe, are well-known examples.

The introduction of *Crepidula fornicata* in Europe's coastal waters belongs to the latter category.

Crepidula's Invasion in Europe.

We are well informed about Crepidula's arrival and establishment in European waters. Relaying of American Atlantic oysters (*Ostrea virginica*) on English beds in the eighties no doubt brought this unwelcome stranger across the Ocean. It established itself first on the Kent and Essex coasts. Soon it rapidly extended its range in the coastal waters of these counties and became by its abundance a menace to the oyster industry there, especially in the estuary of the Thames.

Earlier I discussed how Crepidula extended its range in the coastal waters of western Europe (Korringa 1942). Free swimming larvae are responsible for its distribution over relatively short distances only. The larvae settle down on a suitable piece of substratum (e. g., a stone, pebble or shell), but only if another Crepidula settles down on its shell at some later time is the animal able to produce larvae in its turn. For though now leading a sedentary life, Crepidula retains copulation as an efficient method for fertilization from its free living ancestors. Single individuals are doomed to remain sterile. Though young

individuals are able to crawl about in search for their congeners it is easily understood that a few widely scattered larvae cannot effectively extend the distribution of the species. To Crepidula vast areas without shells or gravel are "deserts", almost unsurmountable obstacles. Only if a couple of adult animals attached to wreckage or drifting seaweed pass through such a desert together, can the formation of a new centre of distribution be started.

Most probably Crepidula crossed the North Sea this way. When a youngster I happened to find the first living Crepidula on the Dutch coast (Zandvoort, October 1926), about a dozen of them attached to a piece of wreckage. If thrown on a sandy or muddy shore without shells or gravel, their chances for survival are very limited indeed. Few places of the Dutch coast offer Crepidula favourable environmental conditions. Of those the Oosterschelde, with its millions of oysters and its huge number of shells scattered there as collectors, is the ideal site for the foundation of a new colony. It was there that Crepidula got its first permanent foothold on the continental shore of Europe. In the year 1929 the first specimens were collected on an oyster-bed in the Oosterschelde. The next year hundreds of them were found and by 1932 and 1933 the situation had become alarming. Later Crepidula has been carried with oysters from the Oosterschelde to the German Waddensea, to the Limfjord in Denmark and to the Dutch Waddensea near the Isle of Texel. Though Crepidula managed to establish a new centre of distribution in the Dutch Waddensea, it did not become a nuisance there. Only where many shells or pebbles offer the possibility to develop a dense settlement, may Crepidula become a real pest.

What makes Crepidula an Oyster-Pest?

Young Crepidulae settle down on hard objects, preferably near or below low water mark. So do oyster larvae. In their efforts to produce young oysters, the oystermen offer the larvae suitable hard and clean objects, so-called collectors. The oyster farmers call any organism other than oysters settling down on the collectors a pest. Especially to be feared are creatures which tend to smother or to crowd out the tiny oyster spat. When several of the fast growing Crepidulae settle down on a small collector, the tiny oyster which chooses this same object as a permanent site has a very poor chance of survival. When Crepidula arrived in the Dutch waters a cheap and efficient collector was used on a large scale: old cockle shells (*Cardium edule*). A great part of the oyster beds was really covered with cockle shells which served as support for a great number of young oysters each summer. To increase the production the shells were regularly cleaned and turned over by careful dredging.

Crepidula came and took the place meant for the young oysters. Several slipper limpets stelled down on every single shell and thus initiated the development of the characteristic slipper chains, permanent associations of individuals of either sex. Scattering shells as collectors became improfitable as it simply turned formerly good oyster grounds into vast Crepidula beds. The oystermen were forced to revert to the old-fashioned tile-collectors, efficient but expensive, as they require much manual labour. Crepidula rarely settles down in large numbers on the lime-coated tiles, as it does not seem to like a rough type of surface. Further the oyster spat is detached from the tiles at an age of only a few months. Possible Crepidulae are left on the tiles to die ashore of exposure.

This occupation of the collectors meant for oyster spat is the most notorious of Crepidula's evil deeds. If once present in great numbers on an oyster bed in their characteristic slightly spiral shaped chains, they deposit so much silt and soft mud that the human foot sinks in it. Thus the beds are rendered unsuitable for oyster planting.

Further, Crepidula is no doubt a nuisance because it ingests oyster larvae which happen to pass by during their pelagic life. Repeatedly I observed that oyster larvae were present in the food strings of Crepidula. Though I can adduce no conclusive evidence that Crepidula is able to kill and digest oyster larvae, there is little reason to presume that a passage through Crepidula's guts and a subsequent deposition in its faeces and silt deposits does anything but harm to the oyster larvae. Considering the enormous quantities of Crepidula once present in the Dutch oyster district, I feel sure that the production of oyster spat was considerably impaired at that time.

It is often suggested that Crepidula, feeding on plankton like the oyster does, must be a serious competitor for food if present in great numbers. I think there is reason to doubt whether Crepidula is guilty of this crime. Since Crepidula gave cause for grave concern our oystermen have rarely or never had reason to complain about lack of growth or lack of fatness of the oysters, though Crepidula occurred in large or very large quantities in the very same district. In the war years particularly, when regular and thorough cleaning of the beds was extremely difficult, Crepidula had a free hand in several parts of the basin of the Oosterschelde. Yet the oysters feeding from the same water that regularly passed the slipper-beds, did very well indeed. As discussed elsewhere (Korringa, 1949) there is ample reason to revise the current ideas about plankton as food and the mechanism of filter feeding. Probably different organisms may specialize on food particles of different dimensions and thus can thrive and fatten without hindering each other. No conclusive evidence has been adduced so far to prove that Crepidula is taking an appreciable share of our oysters' food.

From my paper on shell disease it can be gathered that the presence of many old shells of Crepidula on the surface of oyster beds promote the occurrence and

spreading of this dreaded oyster disease to no small extent. It is my belief that Crepidula is far greater an oyster-pest for this reason than as a competitor for food.

Methods of Control.

Beds heavily or slightly infected with Crepidula, but free from stones or pebbles, can be cleaned effectively with oyster dredges. The powerful boats of the Dutch oystermen work with 4 large dredges at a time. If oysters are present in appreciable numbers, the catch is unloaded and sorted out ashore. One replants the oysters on a well cleaned bed and destroys the slipper limpets by keeping them ashore. If too few oysters are present among the Crepidulae it does not pay to sort them out carefully. In the latter case the catch is usually dumped on specially reserved sand bars, as this is far cheaper than bringing it ashore. The overwhelming majority of the slipper limpets is soon smothered and destroyed by the moving sand. With financial aid from the Government the more important oyster beds were cleaned by dredging in the years 1936 and 1937. A well cleaned bed can be used again for growing and fattening oysters, for Crepidula can only settle down in great numbers where shells or pebbles are abundant. It is prohibited to scatter cockle shells anew as this would undo the effect of the general cleaning within a very short time. Spat collecting should be carried out with tile collectors.

Mechanical cleaning with dredges is feasible, but by no means cheap. It should be repeated regularly. Therefore oyster beds of second and third quality have been left to Crepidula while the oystermen had no use for these beds owing to the seriously reduced oyster stock in the years mentioned above.

Mechanical control of Crepidula had been carried out with insufficient intensity during the war years, the larger vessels being requisitioned by the Germans and Diesel-oil becoming more and more scarce. In order to keep Crepidula from gaining too much ground we tried to find some use for this mollusk, so that it would pay to fish for it. Though Crepidula is edible, and according to me even quite palatable, being both sweet and spicy when uncooked, the edible parts have no attractive looks and are difficult to take out of the shells. Cooked or baked slipper limpets easily become tough as rubber. Attempts were made to sell them as food in Belgium (1941), but a too intense smuggling of other foodstuffs in the boatloads of limpets soon led to an export prohibition. Efforts to create a market for Crepidula in Holland were unsuccessful.

The edible parts of Crepidula contain a rather high percentage of proteins. There was a great demand for proteins as raw material in the food industry during the war years. One of our enterprising oystermen, following our advice, succeeded in finding a market for shucked slipper limpets. It was the factories of the Liebig concern in Antwerp which started to use them in the manufacture of meat-lozenge and similar products. It then became profitable to fish specially for slipper limpets, notwithstanding the increasing costs for boats, fuel and personel. At first the limpets were steamed open and shucked by hand, 100 to 200 girls being employed in a little factory in Arnemuiden (Isle of Walcheren). As it gradually became more and more difficult to obtain the labour, a shucking machine was finally devised and constructed. This machine did its work very efficiently indeed. The shucked meat was dried in hot air before being shipped to Antwerp. We estimate that about 30,000,000 kg. of Crepidula has been worked up this way. Though fishing was mainly where Crepidula was most abundant, the oyster industry profited to no small extent from the development of this new industry.

It is to be regretted that it was found impossible to keep this industry going after termination of the war. The inundation of the Isle of Walcheren made it impossible to use the Arnemuiden factory for a long time. The Liebig concern grew impatient and finally managed to find better and cheaper raw materials. Manufacture of food for chickens from Crepidula's soft parts and the breaking up of its shells for poultry grit was technically possible with the aid of the existing machinery, but administrative and commercial difficulties were encountered. Little practical use is made of Crepidula these days.

The oystermen manage to keep their beds free from Crepidula by dredging but have to go to considerable expense in this. Often biological control of pests is far cheaper than mechanical control, though it may not attain the same degree of annihilation. Biological control of Crepidula is applied in the Dutch waters in two different ways.

In the first place it soon became difficult to produce enough young oysters with the few million tile collectors our oystermen could handle. Though the hard and resistant shells of cockles offer Crepidula a support for many years, this did not appear to be the case with shells as brittle as that of the mussel (*Mytilus edulis*). Thin and brittle mussel shells are produced by the Dutch mussel canneries. After careful experimentation on technical scale the oystermen were allowed to scatter limited quantities of mussel shells on their beds, provided these beds were regularly cleansed and free of any quantity of slipper limpets Young Crepidulae may settle on mussel shells as do young oysters. Thin mussel shells soon break away, however, which renders the young oysters free, and Crepidula dies soon after it loses its foothold. Other Crepidula individuals which possibly settled down on the one using a mussel shell as support, cannot grow to large dimensions if the latter dies young. Therefore thin and brittle mussel shells rarely or never offer Crepidula a chance to develop its large chains of individuals that form entire beds where hard and resistant cockle shells are scattered. Though great

care is required, and thorough supervision of the beds remains a necessity, it appears possible to raise the production of young oysters considerably with the aid of mussel shells, even in a Crepidula infested area. This method is based on the knowledge that Crepidula requires a firm and resistant support to develop the harmful chains of individuals.

A more direct form of biological control is the planting of young mussels on slipper infested beds. The young mussels are scattered in great quantities and keep together with their byssus-threads. They soon smother and suffocate the slipper limpets. This could be carried through on a large scale on beds not used by the oyster industry at the time because mussel farmers ran short of suitable bottoms for the planting of mussel "seed". The mussels grew so well that there was a great demand to obtain permission to participate in this form of biological control. The mussels were dredged away when half grown to be transferred to other mussel beds for further growth and fattening. A large area has been freed of Crepidula this way without any expense to the oyster industry or the State. Gradually the expanding oyster industry is beginning to make use of these beds again.

From the very beginning our oystermen inquired whether some kind of chemical control could not be devised to eradicate Crepidula. Dredging being expensive and time-devouring, chemical control involving little labour seemed attractive. Crepidula being in the same water and on the same beds as oysters, and generally being of a more robust nature than the oyster, there seemed to be little hope for chemical control. Even if some product could be found which killed the slipper limpets, it seemed impossible to pour enough of it in the 500,000,000 m.^{3} of water which fills the basin of the Oosterschelde. Limited quantities of the slipper limpet live on the tidal flats, where a mass attack would be easier but Crepidula being rather closely related to the oyster and well protected by a hard shell, it seemed difficult to kill it by chemical means without killing or injuring oysters and oyster spat.

A special treatment in basins of concrete or masonry ashore is conceivable, however. Mussel shells carrying both oyster spat and Crepidula as well as young oysters covered with slipper limpets can easily be taken ashore for cleaning, grading or other treatment. As a rule every oysterman brings the entire content of his plots ashore for cleaning and grading every other year at least. Therefore, if a method could be devised to free shells and oysters from Crepidula other than the expensive, inefficient and time-devouring method of hand picking, this could be a great help for the Dutch oyster industry. Though Crepidula is stronger and more resistant than oysters and oyster spat in many respects, it appeared to have a weak spot too. Making use of experience gained by Mr. D. McMillin of the Gig Harbor Shellfish Laboratory (Washington, U.S.A.) in his efforts to combate the oyster drill, I started a series of experiments on chemical control of Crepidula. I observed that Crepidula is inclined to lift its shell and proceeds to create a water current for feeding and respiration in some dilute solutions of poison in which oysters and oyster spat keep themselves tightly closed. Apparently the oyster is more readily reacting to certain chemicals than Crepidula. Here we detected Crepidula's Achilles heel! A sojourn of about 2 hours in a very dilute solution of corrosive sublimate in sea water (1:15.000) suffices to injure Crepidula to such an extent that all of them die within a few days, while oysters and oyster spat survive. Though experiments on semi-technical scale have been carried out with good success recently, this new method will be worked out in greater detail in our laboratory before it will be placed in the hands of our practical oystermen. Our oyster farmers face the future with greater confidence since they know that strong weapons for their fight against Crepidula-the-oyster-pest are being forged for them, enabling them to save oyster spat and young oysters which happen to suffer from an intensive set of slipper limpets[1]).

Summary.

Crepidula fornicata, unintentionally introduced in Europe, found a very congenial home in several oyster districts. Especially where shells or pebbles were very abundant did Crepidula develop dense colonies. As Crepidula settles in great numbers on the collectors planted by the oystermen for the production of oyster spat, and crowds out the young oysters, it should be considered as a serious oyster-pest. As well as mechanical combating with dredges, biological methods of control have been used on a large scale in Holland. Chemical control of Crepidula is the latest development and promises to become a very efficient weapon in the hands of the oystermen.

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[1]) According to information received from Dr. Korringa by letter of 15.II.1951, large-scale application of this method has later proved its great practical value and has been adopted by all Dutch oyster farmers. (Secretary-Information).

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13.

Quelques Données Sommaires sur l'Écologie de *Tapes decussatus* (L.).

Par

Herculano Vilela

Parmi les Mollusques comestibles du Portugal, le Bivalve *Tapes decussatus* (L.) est au point de vue économique, le plus important. En effet il se trouve, plus ou moins, tout le long de la côte et il est même très abondant au sud, principalement en Algarve, la seule région du pays où il existe des parcs d'élevage. Son usage dans l'alimentation humaine est aujourd'hui très répandu par tout le pays et, de cette région là, il est aussi expédié pour l'étranger.

Á cause de son importance comme centre de production de *Tapes* nous avons choisi la "Ria de Faro", sur la côte algarbienne pour y réaliser nos études.

Habitat.

L'espèce habite des endroits peu agités, comme les lagunes en communication, permanente ou temporaire, avec l'océan, ou encore dans le voisinage des embouchures des fleuves. Les lagunes toujours ouvertes— "Ria de Faro" et "Ria de Alvor" sur la côte méridionale; et, "Ria de Aveiro", dans la zone nord de la côte ouest, surtout les deux premières, sont les lieux où l'espèce est la plus abondante. La pollution des eaux, due à la navigation et aux activités industrielles, ainsi que la capture exagérée, seront peut-être les causes de leur actuelle diminution près des embouchures des fleuves où l'espèce se trouve normalement, comme le Sado et le Tage, par exemple.

Ces animaux vivent généralement enfoncés dans le sable plus ou moins vaseux, fréquemment associés à d'autres bivalves: des coques, *Cardium edule*; d'autres espèces du genre *Tapes* (*T. pullastra* et *T. aureus*); des lavignons, (*Scorbicularia plana*), etc. Ils sont ordinairement plus profondément enfoncés que les coques, espèce qui d'ailleurs est la plus superficielle de toutes, même les plus grands exemplaires ne descendent pas au delà de 10 à 12 centimètres de profondeur.

La lagune de Faro est située sur la côte méridionale du Portugal limitée au nord par la terre ferme et, au sud, par un cordon littoral sableux avec à peu près 55 kilomètres de longueur, et découpée par des "graus" actuellement au nombre de cinq. L'intérieur très comblé par des alluvions, contient presque seulement de l'eau de mer, car les petits cours d'eau qu'y débouchent n'ont pas d'influence sensible. Une pluie battante peut cependant déterminer une diminution de salinité de l'eau superficielle. La plus basse valeur de salinité de l'eau superficielle pendant les dernières années a été 30·2‰ (en Mars); et la plus élevée, 36·8‰ (en Août). La température de l'eau, très variable avec la période de l'année, le moment de la marée, et avec le lieu (profondeur et distance aux ouvertures sur l'océan), atteint normalement son minimum dans le trimestre Novembre—Janvier pendant lequel on peut enregistrer, dans les années les plus froides, des chiffres inférieurs à 10° C. Les maxima arrivent vers la période Juillet—Septembre dans laquelle on peut trouver jusqu'à 24° C.

Disposition des animaux sur le terrain.

On peut trouver les animaux sur des endroits toujours submergés, mais la plupart habitent les sables qui sont découverts au moins pendant les grandes marées. Pour déterminer comment ils se disposent sur ces sables, l'époque de leur dépôt et à quelle taille, nous avons fait, depuis Septembre 1945 jusqu'à Octobre 1946, six séries de récoltes de sédiment. Chaque échantillon correspondait à une tranche de terrain de 1 décimètre carré de surface et 3 centimètres d'épaisseur. Les animaux de chaque échantillon ont été identifiés, comptés et mesurés.

Avec ce procédé nous cherchions seulement des petits exemplaires, c'est-à-dire des animaux n'ayant pas plus de 10 à 12 millimètres de longueur. En réalité à partir de ces dimensions les individus sont intensivement recueillis et nous ne pouvons donc pas suivre avec sûreté leurs variations quantitatives. Nous avons pu alors vérifier que dans ces bancs la fréquence des animaux augmente irrégulièrement depuis la ligne limite de la marée basse, où elle peut être presque nulle, jusqu'à une distance variable (de 70 à 100 mètres) avec la topographie du terrain, surtout avec la déclive qui n'est pas généralement très accentuée. Depuis cet endroit leur nombre décroît, toujours irrégulièrement, jusqu'à la ligne limite de la marée

haute où les individus sont très rares. L'irrégularité de la distribution des exemplaires sur les lignes plus ou moins parallèles à la ligne de la marée basse nous montre que le dépôt se fait en taches dont les plus grandes occupent les lignes centrales.

Les chiffres moyens d'individus par décimètre carré, très variables avec les lieux, ont atteint leurs plus grandes valeurs aux mois de Novembre et Mars. Nous admettons donc que leur dépôt a commencé avant Novembre et qu'il a décliné après Mars ou peut-être plus tôt. Les moyennes plus élevées ont dépassé la vingtaine par décimètre carré dans beaucoup de cas dans un lieu des plus peuplés: 20·7 — 20·8 — 21·7 — 22·0 — 24·9 — 31·4. Dans d'autres lieux ces moyennes élevées ont été comprises entre 12·5 et 17·4. Le plus grand nombre d'exemplaires comptés dans un échantillon a été de 75.

Commencement de la vie benthique.

En étudiant le Tableau 1, où sont enregistrés les plus petits individus trouvés nous avons pu voir que l'espèce arrive à sa phase benthique en présentant une coquille dont la longueur est comprise entre 0·7 et 0·8 millimètres. Les individus dont la taille est plus petite sont vraiment exceptionnels.

Tableau 1. Exemplaires nouveaux-nés

(plus petits que 1 mm.).

Longeur en mm.	1945 Sept.	Exemplaires par dm.² Nov.	Mars	Mai	Août	1946 Oct.
0·65	0·0	0·0	0·01	0·0	0·0	0·01
0·72	0·05	0·05	0·09	0·0	0·0	0·06
0·78	0·25	0·27	0·33	0·04	0·02	0·23
0·85	0·34	0·54	0·74	0·05	0·05	0·25
0·91	0·47	0·54	0·72	0·06	0·08	0·33
0·98	0·63	0·54	0·79	0·08	0·12	0·30
	1·74	1·94	2·68	0·23	0·27	1·18

Si nous admettons que les exemplaires plus petits que 1 millimètre, et l'hypothèse nous semble vraisemblable, sont "nés", c'est à dire, ont été déposés pendant le mois de récolte (Mars excepté, toutes les récoltes ont été faites vers le milieu du mois ou encore après), nous pouvons supposer que, si toutes les années le phénomène est semblable, les nouvelles générations font leur apparition, dans les sables, dès les mois Août—Septembre jusqu'à Avril—Mai. En effet la moyenne par décimètre carré de ces petits individus qui, en Septembre, Novembre, et Mars, a atteint respectivement 1·74; 1·94; et 2·68 est tombée vers la fin de Mai à 0·23. Ce chiffre-ci et celui du mois d'Août — 0·27 —, sont tellement bas qu'il convient d'admettre un arrêt dans le dépôt des nouveaux individus entre Mai et Août (Fig. 1).

L'examen des gonades adultes confirme cette hypothèse car la ponte a habituellement un arrêt pendant l'hiver et quelques mois du printemps, ce qui d'ailleurs nous mène à supposer que la vie planctonique de l'espèce dès l'œuf aura, peut-être, une durée d'au moins deux mois.

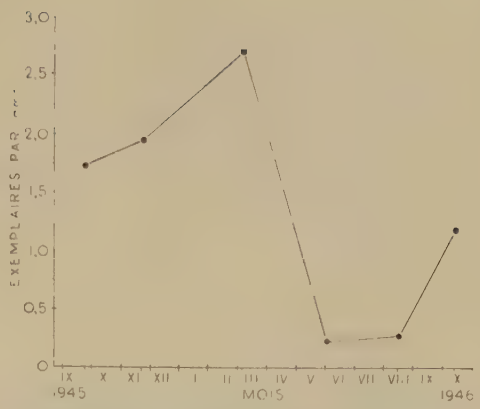

Fig. 1. Variation du nombre d'exemplaires de *Tapes decussatus* (L.) de longueur comprise entre 0·65 et 0·98 mm. pendant une année.

Croissance.

La détermination de la croissance au moyen des "anneaux d'hiver" des coquilles n'est pas sûre, ni même pratiquement possible, parcequ'une multiplicité de causes peut provoquer la formation d'anneaux qui ne correspondent pas au rythme saisonnier. En effet, la distinction entre les "faux anneaux" et les "anneaux d'hiver" ou "anneaux vrais" n'est pas facile. En Algarve surtout le procédé des anneaux est encore moins utilisable puisque dans le sud du pays les différences climatiques saisonnières ne sont pas aussi tranchées que vers le nord.

L'étude des exemplaires contenus dans les échantillons de sédiment nous a montré qu'ils peuvent atteindre de 10 à 12 mm. de taille maximum (la plus grande longueur de la coquille) 3 à 4 mois après sa disposition sur le terrain, et 20 à 22 mm. au bout d'une année. Comme les individus de plus de 12 mm. sont très recherchés, pour leur transplantation dans les viviers ou pour l'expédition directe au marché, selon leur taille, l'étude des grands exemplaires ne peut être faite dûment que dans des viviers expérimentaux.

Dans un de ces derniers, à l'embouchure du Tage (Cova do Vapor), nous avons pu vérifier directement la croissance pendant une année (28 Janvier 1939 — 1er Janvier 1940)

classe 25 mm. croissance moyenne 9·0 mm.
classe 30 mm. croissance moyenne 6·6 mm.
classe 35 mm. croissance moyenne 4.6 mm.

La croissance, qui a présenté en Algarve une allure très semblable, a été pratiquement interrompue pendant les derniers 3 ou 4 mois de l'année.

Sur des animaux préalablement marqués à la lime, maintenus dans un vivier expérimental en Algarve, nous avons pu déterminer directement leur croissance "individuelle" pendant une année (28 Décembre 1947—18 Janvier 1949). Les chiffres obtenus, enregistrés dans le Tableau 2 et Fig. 2, nous montrent que tandis que les individus inférieurs à 20 mm. ont

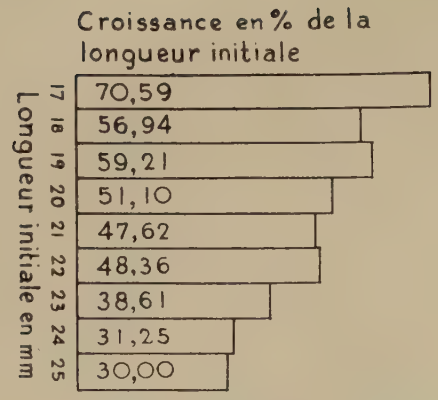

Fig. 2. Accroissement des exemplaires, exprimé en pourcentage de leur longueur initiale.

augmenté entre 57 et 70% de leur longeur initale, les individus mesurant entre 20 et 25 mm. ont grandi, pendant la même période, seulement de 30 à 51%. Les petits individus ont grandi donc très sensiblement plus que les plus grands.

Les individus les plus fréquemment en vente sur le marché ont des dimensions comprises entre 30 et 45 mm., mais dans les bancs naturels j'ai trouvé, malgré leur rareté, des exemplaires de 80 mm. et même un peu plus.

Tableau 2. Croissance individuelle d'exemplaires marqués à la lime

(28. Déc. 1947—18. Janv. 1949).

Nombre final d'exemplaires	Longueur		Croissance	
	initiale mm.	finale (moyenne)	moyenne mm.	% de la long. initiale
3	17	29·0	12·0	70·59
4	18	28·25	10·25	56·94
6	19	30·25	11·25	59·21
16	20	30·22	10·22	51·10
14	21	31·00	10·00	47·62
7	22	32·64	10·64	48·36
4	23	31·88	8·88	38·61
2	24	31·50	7·50	31·25
2	25	32·50	7·50	30·00
58				

Note:—Le nombre initial d'individus était 70; 12 ont disparu pendant l'expérience.

Reproduction.

Pour aborder cet important problème nous avons choisi deux procédés.

a) l'étude microscopique des petits morceaux de gonades dissociés dans une goutte d'eau.

b) l'étude microscopique des coupes sériées de matériel préalablement fixé par le mélange de Bouin et coloré par hémalun-éosine et aussi par l'hématoxyline.

Par le premier procédé, dont les résultats sont publiés au numéro 48 des *Travaux de la Station de Biologie Maritime de Lisbonne*, en employant des individus fixés du formol à 5% nous avons pu arriver aux conclusions suivantes, basées principalement sur la présence ou l'absence de gamètes. La plupart des exemplaires avaient une longueur supérieure à 30 millimètres, mais nous avons observé aussi quelques exemplaires mesurant entre 14 et 30 millimètres.

En voici les résultats:

a) Les gonades ont atteint leur plus grand développement entre Mai et Août.

b) La ponte a commencé entre Août et Septembre ou, peut-être, un peu plus tôt.

En effet, Fig. 3, le nombre d'individus avec des gamètes a augmenté jusqu'à 100% en Juin et Juillet, pour décliner en suite jusqu'à Décembre avec 0%.

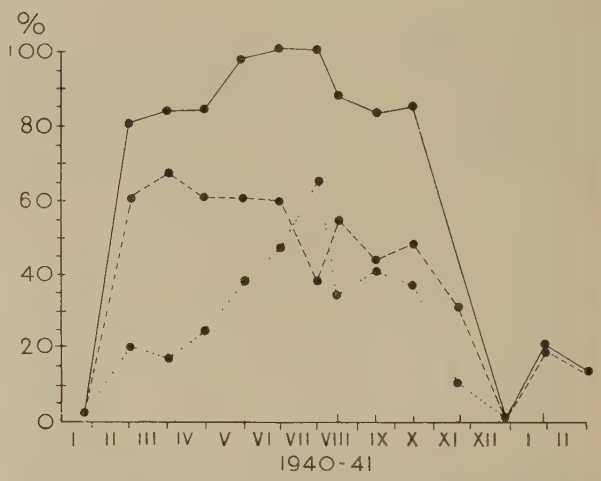

Fig. 3. Variation de la fréquence relative d'exemplaires présentant des gamètes. Total, trait plein; mâles, trait interrompu; femelles, trait pointillé.

c) tous les individus observés portaient seulement un type de gamètes: Spermatozoides ou ovules.

Avec le second procédé nous n'avons vu jusqu'à présent qu'une quarantaine d'exemplaires mesurant entre 4 et 25 mm. de longueur.

L'étude se poursuit mais nous profitons de l'opportunité pour donner, sous réserve, les résultats de nos observations:

a) Nous n'avons trouvé aucun vestige de protandrie.

b) Les plus petits individus avec des gamètes avaient au moins 11 millimètres de longueur.

c) En des exemplaires d'Avril nous avons déjà vérifié l'éxistence d'ovules ou de spermatozoides. Leur nombre augmente jusqu'au mois d'Août.

c) Depuis Septembre jusqu'à la fin de Mars tous les individus ont leurs gonades vides ou en active régénération.

14.

Invertébrés Marins, Comestibles, du Portugal.

Par

Herculano Vilela

Les invertébrés marins comestibles, connus au Portugal sous la désignation vulgaire "mariscos", appartiennent presque exclusivement aux Crustacés et aux Mollusques. Hors de ces deux groupes seulement les gonades — milhas ou milheiras — des Oursins sont aussi comestibles. Le nom "marisco" est plus étendu que "shellfish" puisqu'il peut comprendre les Céphalopodes.

Les mariscos Portugais, les plus fréquemment utilisés sont les suivants:

I. Crustacés.

A. Cirripèdes	Nom vulgaire
Pollicipes cornucopia Leach	Perceve, Percebe, Perceba

B. Décapodes	Nom vulgaire
Parapenaeus longirostris (H. Lucas)	Gamba
Leander serratus (Pennant)	Camarão
Crangon crangon (Linné)	Camarão mouro, Camarão branco, Cabra
Nephrops norvegicus (Linné)	Lagostim
Homarus vulgaris H. M.-Edwards	Lavagante, Labugante, Navegante
Palinurus vulgaris Latreille	Lagosta
Maia squinado (Herbst)	Santola, Arola, Burro
Maia verrucosa H. M.-Edwards	Santola, Arola, Burro
Cancer pagurus Linné	Sapateira, Centola, Caranguejola
Cancer bellianus Johnston	Sapateira
Polybius henslowi Leach	(pas comestible)
	Pilado, Mexoalho
Portunus puber (Linné)	Navalheira
Carcinides maenas (Linné)	Caranguejo, Caranguejo morraceiro
Eriphia spinifrons (Herbst)	Caranguejo, Caranguejo mouro
Uca tangeri (Eydoux)	Cavalete, Cava terra

II. Mollusques.

A. Bivalves	Nom vulgaire
Gryphaea angulata Lamarck	Ostra, Carcanhola
Pecten maximus (Linné)	Vieira, Leque
Mytilus edulis Linné	Mexilhão
Cardium edule Linné	Berbigão
Venus verrucosa Linné	Pé de burro
Venus gallina Linné	Pé de burrinho
Dosinia exoleta Roem	Amêijoa redonda
Tapes decussatus (Linné)	Amêijoa, Amêijoa boa
Tapes pullastra (Montagu)	Amêijoa, Amêijoa macha
Tapes aureus (Gmelin)	Amêijoa, Amêijoa bicuda
Donax trunculus Linné	Cadelinha, Conquilha
Donax vittatus (Da Costa)	Cadelinha, Conquilha
Solen marginatus Pennant	Longueirão, Lingueirão, Navalha, Canivete
Ensis ensis Linné	Longueirão, Lingueirão, Navalha, Canivete
Solenocurtus	Taralhão
Scrobicularia plana (Da Costa)	Lambujinha, Amêijoa chatinha, Amêijoa de gato.

B. Gastéropodes	Nom vulgaire
Patella vulgata Linné	Lapa
Patella athletica Bean	Lapa
Murex brandaris Linné	Búzia
Murex trunculus Linné	Búzio
Purpura haemastoma Linné	Búzio
Purpura lapillus (Linné)	Búzio
Trochochlea lineata (Da Costa)	Burrié, Caramujo
Gibbula obliquata (Gmelin)	Burrié

C. Céphalopodes	Nom vulgaire
Sepia officinalis Linné	Choco
Loligo vulgaris Lamarck	Lula
Octopus vulgaris (Lamarck)	Polvo

15.

Shellfish in the Netherlands.

By

B. Havinga

Crustacea.

The only species of Crustacea of general commercial value is the common shrimp (*Crangon vulgaris*); lobster (*Homarus vulgaris*) and crab (*Cancer pagurus*) occur in small quantities and are only of local importance.

Shrimp.

General. Shrimps are caught in all the estuaries of the Scheldt, Meuse and Rhine, in the Wadden Sea and off the open North Sea coast. In all these waters shrimps may be found in great quantities, on the hard barren sand bottom of the North Sea shores as well as on the mud bottom of the inshore waters. They used to occur in great numbers on the very soft mud in the central basin of the now enclosed Zuider Sea.

Shrimps are caught with a fine-meshed otter-trawl or with the old fashioned beam trawl. In the Wadden Sea particularly many fishermen prefer the beam trawl, they fish with 2 nets, one at each side of the vessel.

There are shrimp fishery centres in the southern part of the Netherlands, (Breskens, Arnemuiden, Stellendam) as well as in the north (den Helder, Oudeschild, Harlingen and Zoutkamp). Formerly, when the product was always in sufficient demand, and no restrictions on the fishery were necessary for economic reasons, some villages gained nearly their whole livelihood from the shrimp.

Shrimps are not caught for human consumption only, large quantities of small shrimps being landed for the manufacture of dried shrimps or shrimp meal. In the Lauwer's Sea and Dollart it is customary to dry the greater part of the catches, because there is only a very restricted demand for human consumption. The small shrimps used for drying do not consist only of young ones; mature males, too small for human consumption, occur in great quantities also.

In Table I the catches in the different districts and the totals are shown for a number of years taken at random.

Fluctuations in the stock. The figures in Table I are not always a good measure for the density of the stock. In the years between the two wars especially, restrictions were often necessary in order to avoid glutting of the market. We know from experience, however, that great fluctuations may occur. In some years shrimps are abundant, and one has to be careful that the market is not glutted, while in other years the catches may be so poor that the fishing is scarcely profitable.

In such poor years the fishermen sometimes call for protection of the stock, especially by the prohibition of the landing of small shrimps.

Table I. Catches of shrimps for human consumption and for drying, in different districts of the Netherlands, in 1000 kg.

Year	South. Districts		Zuider Sea	Wadden Sea		Lauwers Sea, Dollart		Total	
	consump.	drying	consump.	consump.	drying	consump.	drying	consump.	drying
1920	4,264	—	1,885	339	—	394	—	6,882	—
1925	3,726	—	1,910	577	—	1,626	—	7,839	—
1930	3,699	2,700	2,313	1,235	900	113	3,602	7,360	8,202
1935	2,213	3,800	—	319	2,200	65	4,965	2,597	10,965
1939	2,348	8,300	—	353	2,700	111	11,272	2,812	22,272
1946	1,648	60	—	573	206	406	2,000	2,627	2,266
1947	2,660	1,450	—	975	700	163	4,900	3,798	7,050
1948	2,683	356	—	691	1,345	595	1,550	3,969	3,251

Investigations (Havinga, 1930) did not lead, however, to the introduction of protective measures and up to now the shrimp is not protected at all.

I got the impression that although the fishery is carried out intensively in the Netherlands, it is well balanced by the enormous productivity of the shrimp. This impression was corroborated by the yields immediately after the war. During the war, especially the latter part, the fishery was hampered by the seizing of numerous vessels and by other acts of the Germans. There are no reliable statistics for 1945, but experience showed that the catches then were subnormal. 1946, too, shows rather low figures. The limited activity of the fishery during the years of war, therefore had no favourable influence on the stock.

That fishing apparently has only a slight influence on the stock might be explained by the supposition that the natural mortality is very great as compared with the mortality caused by fishing, and that it is, therefore, the natural influences that are responsible for the variations of the stock. Shrimps are a common food for many species of fishes that are very frequent in the shrimp areas: whiting, dab, *Cottus scorpio*, *Zoarces viviparus*, *Trigla spec. div.* These fishes occur in millions and the quantity of shrimps they take as food will amount to tens of millions of kilogrammes. The extreme abundance of a fish preying on shrimps, e. g., whiting in 1945 and 1946, will presumably do much greater harm to the stocks than an increase in the intensity of fishery.

In accordance with this supposition no protective measures, such as a minimum size of shrimp or net, or closed seasons, have ever been advised in the Netherlands.

Towards the end of 1948 the shrimp catches began to fall considerably, first in the southern districts, but later on in the Wadden Sea also. The catches decreased to such an extent that many vessels abandoned the shrimp fishery. It is supposed that the drop in catches is caused by downward natural fluctuations in consequence of the low temperature in the severe winter of 1946—47, perhaps accentuated by the great numbers of dabs and flounders on our coast in 1948.

The **migrations** have been described extensively in my paper quoted above, and as no investigations have been carried out in the Netherlands on this subject since its issue, I shall restrict myself now to reference to this paper.

The same migrations as have been found in the Netherlands have been described in a recent paper by Lloyd and Yonge (1947).

It is certain that both salinity and temperature are the stimulating factors for this migration, but, in addition, investigations of Broekema (1941) have shown that there is an interaction between salinity and temperature. She found that with increasing temperature the salinity optimum shifts downwards; in two-year-old animals at 4° a salinity of 33‰ proved to be optimal, whereas at 20° C. the optimal salinity was 29‰. For one-year-old animals the optimal salinity proved to be very low at high temperatures, viz.: about 15—20‰ at 20° C.

In osmosis experiments she could prove that the difference between internal and external concentration is greater at high than at low temperatures; both when the animal is hypotonic or hypertonic with respect to its medium. This explains why extremely low or high salinities can better be endured when the temperature is high.

It seems likely that the results of these laboratory experiments will be of great value in explaining the migrations observed in nature.

Lobster.

General. In a country such as the Netherlands, with its flat shores consisting of sand or mud, one would not expect to find lobsters. Nevertheless a fishery for lobster exists, and although the lobster makes only a very moderate contribution to our inshore fisheries, it seems worth while to mention it here from the point of view of ecology and the measures in force for its protection.

It was not until about 1900 that the attention of the fishermen was drawn to the occurrence of lobsters in the Oosterschelde. This was not because up to that time the fishermen had not observed the existence of the lobsters, but because they were extremely rare.

The lobster, a resident of stony or rocky bottoms, has found an adequate substitute in the large masses of heavy stones that have been dumped at the foot of the dikes in order to defend them against the destructive action of the sea. These stones have been dumped along all the dikes where strong tidal currents occur. But only in the Oosterschelde has a population of lobsters developed, only a few individuals occurring at the mouth of the Westerschelde and a very few at den Helder, at the entrance of the Wadden Sea. In the other areas it is supposed that the periodical presence of water of too low a salinity prevents the lobsters from establishing themselves.

How the first individuals immigrated is not known for certain, perhaps they came by natural means from the North Sea, but it is also possible, that they developed from the rather large numbers of eggs attached to the berried females that are always present in lobsters imported by the trade.

That the lobsters did not live in the Oosterschelde long before 1900 can be demonstrated by the statistics of the catches with weirs, of which a fairly constant number have been in use for a long period. During the period 1888—1897, no lobsters were caught at all in 7 years, the maximum in the remaining years was 3; from 1898—1907 the minimum was 9, the maximum 38; and from 1908—1917 the minimum was 12, and the maximum 52 (Havinga, 1921).

Fluctuations in the stock. Nearly all lobsters are caught with lobster pots attached to long ropes in great numbers. The catches, the numbers of pots, and the catch per pot per year, are shown in Table II.

This table demonstrates very distinctly that the

Table II. Catches of lobsters in the Netherlands (Oosterschelde), in 1000 kg, number of pots and catches per pot per season.

Year	Total Catch	No. of Pots	Catch per Pot
1911	5	1,810	3·0
1916	11	2,320	4·9
1921	23	3,052	7·4
1926	43	4,435	9·8
1931	15	7,968	1·9
1935	21	5,464	3·9
1938	13	4,440	2·8
1946	5	1,655	3·3
1947	5	1,331	3·6
1948	5	1,842	3·0

catches were rapidly increasing in size up to about 1926, whereas from that year on there was an equally rapid decline, notwithstanding the fact that the number of pots has been increasing considerably up to 1931. Correspondingly the catches per pot show a continuous decline since 1926 when a maximum was reached. The particularly low figure for 1931 was caused by the introduction in that year of another closed season with the special purpose of restricting the fishery.

As other factors that might have affected the stock are not known it seems likely that we have here a typical example of overfishing. This could occur easily in the Oosterschelde, as the grounds suitable for lobsters are not extensive, and the intensity of fishing on these small areas is very great. I have estimated that during the years of intensive fishing 70—80% of the lobsters of legal size were caught annually.

Protective measures. The serious decline in catches was not prevented by a series of protective measures that were in operation from the very beginning of the fishery. The fishery is restricted by a closed season, a legal minimum size and a prohibition on the landing of berried females.

The fishery is only allowed from April until July 15th. The legal size is 11 cm. for the length of the carapace. This is a rather uncommon standard of length, but is proves very satisfactory in practice, since it can be measured very accurately and easily. This length of carapace, from the point of the rostrum to the end of the carapace, corresponds to a total length of about 25 cm.

The saving of berried females is a practice that is not in common use. I think, however, that it is a very effective way of preventing overfishing. This kind of restriction does not only involve the saving of the female herself and her potency to produce one or more following batches of eggs, but also her progeny which, in a stock of constant magnitude, is roughly equivalent to 4 mature individuals.

Against this kind of restriction the objection is often made that illegal removing of the eggs is rather easy. The experience, however, that we have had in the Netherlands is that such illegal removing is not a common practice, it takes a considerable time to brush off the eggs so thoroughly that none are left. In addition the fishermen feel that they are performing a good deed in saving the berried females.

Crabs.

The fishery for crab is of very little importance. Crabs, like lobsters, live at the foot of the dikes on the dumped stones, but the most preferred habitat is not exactly the same as for the lobsters. Generally they occur in greater quantities nearer to the open North Sea than do lobsters. Perhaps they are more sensitive to water of low salinity, and certainly they are very sensitive to low temperatures during severe winters. After a cold winter the catches are always very low, perhaps because of a great mortality, but it is also possible that the low temperature caused a migration seaward such that the animals are not back again by the fishing season of the next spring. If the low temperatures caused a great general mortality, it would be difficult to explain the rather rapid recovering of the fishery.

In the cold winter of 1946—47, however, the crabs died, even in the North Sea at considerable distances from the coast.

Owing to the little value to the fishery no protective measures exist for the conservation of the stock.

Mollusca.

General.

The species that are of commercial value in the Netherlands are: oyster (*Ostrea edulis*), mussel (*Mytilus edulis*), cockle (*Cardium edule*), clam (*Mya arenaria*), whelk (*Buccinum undatum*), and periwinkle (*Littorina littorea*). To these species may be added the slipper limpet (*Crepidula fornicata*). This species, however, forms the subject of a special paper prepared for this meeting by Korringa.

In most of the species mentioned above a decline in production has occurred in the last 3 or 4 decennia. This is partly due to economic factors, partly to biological factors. With the exception of oysters and mussels, of which small quantities are eaten in the Netherlands, nearly all of the Mollusca have to be exported. Consequently the industry depends almost exclusively on the export facilities.

Oyster.

In value the oyster is the most important mollusc in the Netherlands. Up to about 1920 considerable quantities of oysters were caught on the public banks in the Wadden Sea; in some years a catch of 2 million oysters was obtained. Overfishing and the disease in 1920 and following years depleted the banks to such an extent that the fishery was discontinued. Now the oyster is one of the rarest species in the Wadden Sea.

The whole production is now restricted to the oyster culture in the Oosterschelde. A description of this

culture has been given by HAVINGA (1932) and by KORRINGA (1946, 1947, 1949).

The production of oysters is shown in Table III. There is a distinct difference in the quantities produced up to about 1930 when the production varied between 2 and 3 million kg. annually, and afterwards when it did not reach 1·5 million kg. The principal reasons for this decline were the invasion of *Crepidula* and the outbreak of a serious disease, both described by KORRINGA in contributions to this meeting.

In 1934 a minimum of 555 tons was reached, but the industry soon recovered, thanks to the results of research and to the relaying of imported young French oysters. Up till now, however, it has not been possible to reach the level of the period previous to 1930, and to maintain the present production of about 1·5 million kg., it is still necessary to import young oysters from France for relaying.

KORRINGA has shown that the productivity of the Oosterschelde is not unlimited. If there are too many oysters on the banks, as has sometimes been the case, growth and quality are affected.

Mussels.

The quantities fished and produced in the Netherlands can be seen from Table III. There are 2 centres for this industry; the Wadden Sea and the Oosterschelde. In the Wadden Sea by far the largest quantities are fished from natural banks, artificial culture is insignificant. The mussels from the Wadden Sea are not used only for human consumption, but also for poultry food, especially on the duck farms.

Before the enclosure of the Zuider Sea the productivity of the Wadden Sea was much greater than it is now. The reason is not exactly known; perhaps the increased velocities of the tidal currents make the habitat more unfavourable; it is also possible that the intensive fishing has a marked influence.

The figures in Table III denote only the quantities of mature mussels, but in addition large quantities of young from the natural banks in the Wadden Sea are fished and transported to Zealand for relaying on the mussel beds there. The Wadden Sea is the most important source of young mussels needed for the mussel culture.

During recent years it has often been difficult to obtain a sufficient quantity of young mussels for this purpose. It will, however, be far from easy to develop methods to improve this, especially as the young mussels for relaying must be produced at a very low cost. Some work has been done on the setting of the larvae and the young (MAAS GEESTERANUS, 1942).

The whole of the production in Zealand comes from artificial culture. A description of this culture has been given by HAVINGA (1932).

In the period from 1898 until 1918 the mussels in Zealand were often affected by a very serious disease that depleted a great part of the banks. The symptoms were that the mussels became extremely meagre, and that the byssus was released so that the clusters were broken up. The cause of the disease has never been found. It is supposed that the large scale introduction of motor vessels, that entailed a much more intensive cleaning of the banks, is responsible for restoring the banks.

Table III. Production of commercial Molluscs in the Netherlands in 1000 kg.

Wadden Sea, W; Zealand, Z; Total, T.

Year		Oyster	Mussel	Cockle	Clam	Whelk	Periwinkle
1912	W	83	3,328	320	—	321	1,853
	Z	2,953	37,730	500	138	32	253
	T	3,036	41,058	820	138	353	2,106
1925	W	7	26,496	688	—	494	1,104
	Z	1,310	46,308	336	270	44	127
	T	1,317	72,804	1,024	270	538	1,231
1930	W	1	24,720	262	—	181	1,065
	Z	2,381	36,695	145	50	72	116
	T	2,382	61,415	407	50	253	1,181
1935	W	—	28,186	193	—	233	90
	Z	643	38,800	246	8	123	227
	T	643	66,986	439	8	356	317
1939	W	—	25,911	—	—	113	56
	Z	930	39,385	355	12	83	221
	T	930	65,296	355	12	196	277
1946	W	—	2,001	—	—	140	27
	Z	1,334	31,015	177	85	32	79
	T	1,334	33,016	177	85	172	106
1947	W	—	12,412	—	—	92	9
	Z	1,149	56,196	192	?	24	65
	T	1,149	68,608	192	?	116	74
1948	W	—	23,856	2	?	91	47
	Z	1,458	50,647	232	?	26	92
	T	1,458	74,503	234	?	117	139

Early in September of this year (1949) an outbreak of a disease was again reported from one part of Zealand that caused a very great local mortality. The symptoms were the same as mentioned above.

But this time a parasitic copepod, *Mytilicola intestinalis*, could be found in great numbers in the intestine of the diseased animals and it is fairly certain that they were the cause of the mortality.

Cockles and Clams.

These species are of very little importance in the Netherlands. The production could certainly be increased, but the trade, exclusively export, can only deal with small quantities. It was customary to export the Wadden Sea cockles to England and the Zealand cockles to Belgium. As the Belgian demand was the more stable one, the production in Zealand was more stationary while in the Wadden Sea it was practically discontinued through lack of export facilities (Table III).

Whelk.

The whelk, too, shows a decrease in catches, but in this case a declining demand is not the cause, and presumably the stocks have been overfished. In the Wadden Sea there is a fairly intensive fishery exclusively for whelks during the winter, and as they only occur on a special type of bottom, preferably hard sand mixed with shells, the area in which they are found is small, and due to the high prices the fishermen get for the product, overfishing may easily result.

As long as oysters were present, there was a combined fishery for oysters and whelks, as both species prefer the same type of bottom.

In Zealand the greater part of the landings are caught during cleaning operations and fishing on oyster and mussel banks, direct fishing for whelks is no longer of great importance. Correspondingly, the catches have not decreased a great deal.

Periwinkle.

The landings of periwinkles have shown a sudden and considerable drop since 1932. The main source was the extensive eel-grass fields in the Wadden Sea. On the leaves lived enormous quantities of periwinkles and they were fished with a kind of small dredge from sailing vessels.

In 1932 the eel-grass died away suddenly through a disease, and together with it the fishery for periwinkles. The relatively small catches afterwards are being made by collecting by hand along the dikes and on the flats at low tide.

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16.

On the Crustaceans of Commercial Importance in Danish Waters.

By

Erik M. Poulsen

Introduction.

In the Danish Seas four species of crustaceans are of importance to the fishery, viz.:

Latin name	English name
Homarus vulgaris M. Edv.	lobster
Nephrops norvegicus L.	Norway lobster
Leander adspersus (Rathke)	prawn[1])
Pandalus borealis Krøyer	deep sea prawn

[1]) In the catches are often found a few specimens of *Leander squilla* (Latr.) and, more rarely, *L. serratus* (Penn.).

Two other species of edible crustaceans, viz., the shrimp (*Crangon vulgaris* Fabr.) and the edible crab (*Cancer pagurus* Leach) are common in Danish waters, but are not fished.

The annual quantities and values of the Danish fishery for the above-mentioned 4 species were for the two years 1946 and 1947:

	tons	1000 kr.	Value % of yield of all fisheries
Homarus vulgaris	133	1,477	0·9
Nephrops norvegicus ..	1077	1,999	1·3
Leander adspersus	271	1,650	1·0
Pandalus borealis	288	1,728	1·1

The total percentage value of these species is 4·3 %, together they rank as No. 6 in importance, with the eel just above and the mackerel just below.

The fisheries for lobster and prawn have been in existence for a long time, but those for Norway lobster and deep sea prawn in Danish waters began in 1930. In spite of this, the two new fisheries are now of greater value than the old ones.

The Lobster.

Distribution and Fishery.

In Danish waters the lobster is found and fished for in the North Sea, the Skagerak, the Limfjord, the Kattegat and the northern part of the Belt Sea. A few are found as far south as in the Sound and the southern Great Belt, i. e., at a salinity at about 20 ‰.

The fishery is carried out almost exclusively with traps baited with dead fish. The following table gives the quantities in tons caught in our various waters as means of the years 1946 and 1947:

North Sea	36 tons
Skagerak	56 —
Kattegat	36 —
The Limfjord	5 —
The Belt Sea and the Sound	1·5 —
Total...	134 tons

The fishery for lobster in our waters is mostly a summer one, with the greatest yields in May to September, as can be seen from the following table showing the mean monthly catch in kg. for the years 1946—48 from Løkken, the most important lobster fishing port of the Skagerak.

	kg.		kg.
Jan. to March	0	August	3432
April	604	Sept.	2913
May	1821	Oct.	817
June	2518	Nov./Dec.	0
July	2138		

Variations in the Yield of the Fishery.

The total yield (1896—1948) of the Danish lobster fishery is shown in Figure 1 together with the yield from the Limfjord alone. In the nineties the total

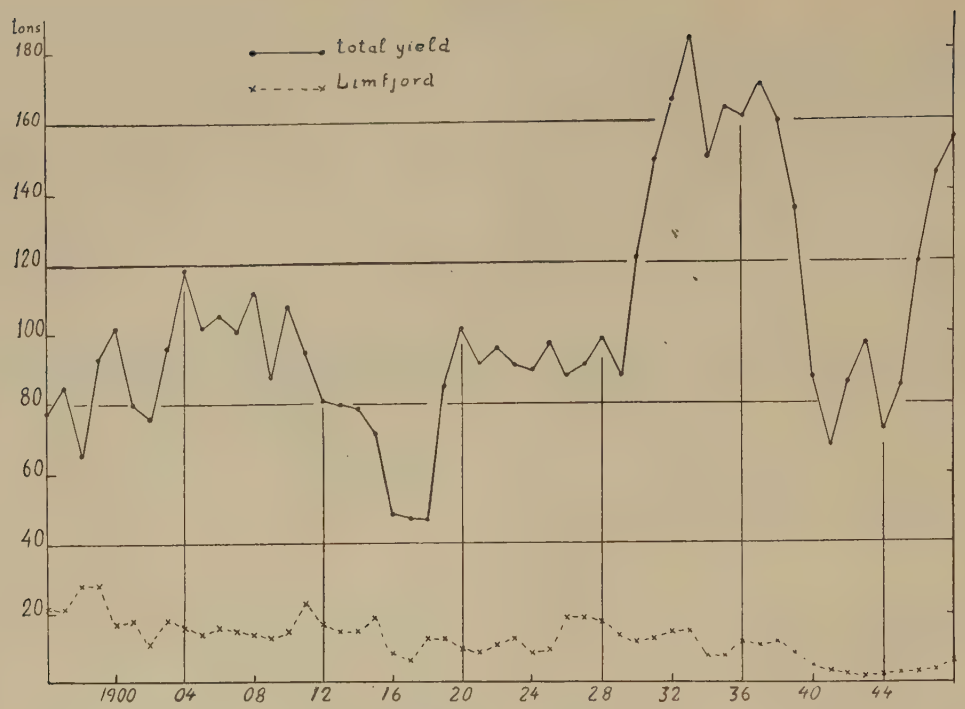

Fig. 1. Total yield and yield in the Limfjord alone of the Danish fishery for Lobster (*Homarus vulgaris*) in the years 1896–1948.

annual yield was about 80 tons, from 1903 to 1911 it was a little higher, about 100 tons, then it decreased steadily for some years and in 1916—18, during the first great war, it was only about 50 tons; it increased again rapidly and from 1920—29 it varied between 90 and 100 tons; a further increase occurred in the thirties, and from 1931 to 39 the yield varied between 130 and 180 tons. During the second great war 1940—45 the catch was again lower, only between 70 and 100 tons. During the years after the war a new increase has taken place, up to 150 tons.

Within the period a very considerable increase in yield has occurred in the Skagerak and the North Sea until the present time and in the Kattegat up to 1937, whereas a very strong decrease has occurred in the Limfjord. During the last decade the catch from the Kattegat has also decreased.

Based on these fluctuations it may be stated that the stock of lobster is not yet overfished in the North Sea and the Skagerak, but that considerable overfishing has taken place for many years in the Limfjord, and for the last ten years in the Kattegat as well.

A better understanding of the question of overfishing is gained by examining the catch yield in comparison with the intensity of fishing.

For the later part of the period under consideration the lobster trap has been the only gear used for the lobster fishery in the above-mentioned waters, and no appreciable alterations in the size and design of the trap have been introduced. By examining the yearly catch of lobster per trap during the period (from the year 1920) we can see how the stock of lobster has been affected by the fishery, since the catch per trap will vary according to the density of the stock.

The yearly catch in kg. per 1 trap taken over 4-yearly periods during the years 1920—47 in the various waters is as follows; in ( ) are stated the number of traps (00 omitted):

	kg. per 1 trap.		
	Skagerak + North Sea	Kattegat	Limfjord
1920/23	5·3 (115)	8·2 (24)	4·1 (26)
1924/27	5·1 (106)	10·6 (20)	3·6 (38)
1928/31	6·3 (122)	10·1 (22)	3·2 (43)
1932/35	5·8 (187)	12·2 (38)	2·7 (44)
1936/39	4·1 (197)	8·7 (72)	2·5 (44)
1940/43	2·9 (157)	4·2 (79)	1·6 (22)
1944/47	5·4 (140)	4·3 (76)	2·4 (18)

In the Skagerak and the North Sea the catch per trap is about the same now as in 1920/23. In the Kattegat and the Limfjord the catch now, however, is only half the 1920/23 amount.

The results of a consideration of the yearly fluctuations in catch, as well as catch per trap can thus be summarized in the following way: in the North Sea and the Skagerak the depletion of the stock is at the most only of slight importance. In the Kattegat a considerable depletion has been going on during later years. In the Limfjord the depletion has been going on for a long period and is a very serious matter, causing a gradual abandonment of the fishery.

Growth.

The growth of the lobster takes place only in the very short period just after the casting of the shell, when the new shell is more or less soft. Three lobsters which were kept in tanks, all females, cast their shells between 7—14 days after the hatching of the larvae, and after 18—20 days the new shell was completely hard. The growth of the 3 specimens was: 24—25·5 cm., 24—25·5 cm., 26·0—27 cm., i. e. ca. $1^1/_2$ cm.

Three **marking experiments** (Figure 2) with lobster have been carried out in Danish waters, viz.: 12. August 1924, 14 miles WNW. of Løkken, Skagerak, 17 m. depth, 100 specimens; 8. May 1925, 25 miles NW. b. N. of Løkken, Skagerak, 35—38 m. depth, 70 specimens (E. M. Poulsen, 1927); and 29. August 1929, 1 mile N. of Vodstrup Hage, Limfjorden, 4 m., 100 specimens.

The markings were made by means of incisions in the caudal fin. The locality and the size of the lobster were indicated by the form and the position of the two or three incisions made.

From the marking experiments in the Skagerak 13 specimens recaptured within 12 months after liberation had cast their shells; the mean growth of these was 2·5 cm. Three more, which were recaptured 21 months after liberation, had grown 4·9 and 10 cm.; at least two of these must have cast their shells more than once.

From the experiment in the Limfjord 7 of the specimens recaptured within the first 11 months had cast their shells; their mean growth was 2·9 cm., or about the same as in the Skagerak.

The material further indicates that the smaller lobsters grow more rapidly than the bigger ones, and that the growth of the males is more rapid than that of the females; the percentage growth of 13 males which had cast their shells within a year of liberation was 12·2%, whereas 9 corresponding females had grown only 8·8%.

Measurements of samples caught in traps were carried out (Table 1).

No size-groups corresponding to the growth during each casting of the shell appear in the material.

It is obvious from the measurements that the lobsters are somewhat smaller in the Kattegat and the Limfjord than in the Skagerak + the North Sea. However, there is no proof that this is due to a biological difference between the two stocks. It may well be due to a stronger fishery in the former waters. The largest mean size is found in the sample off Løkken 8. May 1925. This sample was caught on a reef far from the shore, where fishing had been going on for less than a year, and the large mean size may very well be due to this. In the coastal waters off Løkken and off Klitmøller, where lobster fishing has taken place for a number of years, the mean size is considerably lower.

In the Skagerak and the Kattegat only one berried female below 25 cm. (23 cm.) was found, and the mean size of the berried females was about 27 cm. In the Limfjord, however, berried females down to a size of 21 cm. were found, and the mean size of the berried females was 1—2 cm. below the mean size in the Skagerak and the North Sea.

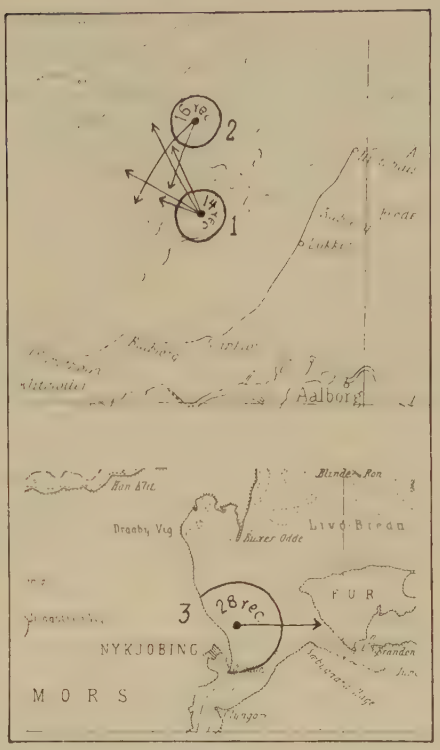

Fig. 2. Marking experiments with lobsters.
In 1 and 2 (Skagerak) the recaptures (14 and 16 resp.) within 4 miles from the place of liberation are not given separately; neither in 3 (Limfjord) the recaptures at a distance within 1.5 mile.

Migrations.

The three marking experiments (Figure 2) show that the migrations of the lobster cover only very small distances. In the Limfjord, out of 24 recaptures within the first year and 2 further within the 2nd year, none were obtained farther than $1^1/_2$ mile from the place of liberation. Of three lobsters recaptured in the 3rd year two were caught less than one mile from the place of liberation, and one 4 miles away.

From the experiments in the Skagerak 30 out of 36 recaptures (with place of recapture stated) were made within ca. 4 miles from the place of liberation, whereas six specimens had migrated 10 to 15 miles.

The percentages of recaptured specimens were as follows:

Place of Liberation	No. of spec.	Within 1 year	Within 2 years	Within 3 years	total
14 miles WNW. of Løkken ...	100	19	4	—	23
25 miles NW. b. N. of Løkken	70	20	6	—	26
Vodstrup Br., Limfjord	100	24	2	3	29

The percentage recapture is thus a little higher in the Limfjord than in the Skagerak. The recaptures during

Table 1. **Analyses of lobster catches from Danish Waters.**

The italic figures refer to berried females only.

cm.	14 M. WNW. of Løkken 12/8 1924	25 M. NW. b. N. of Løkken 8/5 1925	Off Klitmøller N. North Sea 25/7 1930	Off Strandby N. Kattegat 25/7 1930	Vodstrup Broad the Limfjord 29/8 1929
16	1	—	—	—	—
17	1	—	—	—	—
18	5	1	—	—	—
19	2	—	—	—	3
20	8	—	—	—	13
21	12	2	10	30	15 — *1*
22	8	7	8	12	16
23	7 — *1*	5	4	6	16 — *2*
24	1	10	8	3	13 — *1*
25	7 — *5*	4 — *1*	4 — *2*	3 — *1*	19 — *1*
26	9 — *8*	24 — *6*	5 — *2*	3	16 — *2*
27	7 — *4*	22 — *7*	2 — *1*	1	11 — *4*
28	6 — *5*	26 — *7*	3 — *2*	—	5 — *1*
29	7 — *4*	14 — *2*	—	—	4
30	9 — *7*	18 — *3*	1 — *1*	—	6 — *1*
31	3 — *2*	11 — *3*	—	—	4
32	1 — *1*	9 — *1*	—	—	6 — *2*
33	1 — *1*	7 — *2*	—	—	1
34	2 — *1*	8	—	—	2
35	1	3	—	—	—
36	—	4	—	—	—
37	1	—	—	—	—
38	1	2	—	—	—
Total...	100 — *39*	177 — *32*	45 — *8*	58 — *1*	150 — *16*
Mean length of spec. above 21 cm...	26·4 — *28·0*	28·4 — *28·3*	23·7 — *26·9*	23·1 — *25·0*	25·3 — *26·5*

the 1st year amount to little more than $^1/_5$ of the number of lobsters liberated.

Propagation.

As already mentioned the smallest berried females found measure 21 cm. The number of berried females below 25 cm., however, is only small, 5 out of a total of 95. The spawning takes place in July (and August) and the hatching a year later at almost the same season.

The table below shows the percentage of the sexes. The ratio of males to females varies to some degree; on the whole the catches yield a few more females than males. For the calculation of the number of berried females only those more than 25 cm. long were considered; the number of berried females below this size being very small. Apart from the small sample from Strandby with only 4 females above 25 cm., it is obvious that the percentage of berried females is biggest, viz. 69 and 80 %, in July and in the first half of August. This is the time when females with both year-old eggs (red) and newly spawned eggs (black) are present. The percentage is much smaller, only 25 and 35, in the latter half of August when only females with newly spawned eggs are present, and in May when only females with older eggs occur. The low percentage of berried females clearly shows that the females do not spawn more frequently than every second year. Judging from the figures alone (from May and end of August) spawning should take place only every third year; but the possibility that the berried females on account of their more cautious behaviour, are not caught so frequently in the traps as the not-berried ones must be considered.

Proportion of males, females and berried females in the samples.

	Total No.	Males		Females			Berried females > 25 cm.		Number of berried females with	
		No.	%	No.	%	total	No.	%	black eggs	red eggs
Løkken, May 8th	177	71	**40**	106	**60**	91	32	**35**	35	0
Klitmøller, July 25th	45	23	**51**	22	**49**	10	8	**80**	5	3
Strandby, July 25th	58	33	**57**	25	**43**	4	1	**25**	1	0
Løkken, Aug. 12th	100	35	**35**	65	**65**	48	33	**69**	26	7
Vodstrup Br., Aug. 29th	150	64	**43**	86	**57**	44	11	**25**	11	0
Total ...	530	226	**43**	304	**57**	197	85	**43**	78	10

Protection.

In Danish waters the lobster is at present, and has been for a long period, protected by a size limit of 21 cm. measured from the point of the rostrum to the hind margin of the telson (its brim of hairs not included). Further, in the Limfjord, all lobster fishing is prohibited in July. A certain increase, for example, up to 24 cm. may be advisable, as only very few of the berried lobsters are protected by the present size limit. A closed season in the middle of the summer, i. e., in the period when the hatching occurs, and when the ecdyses are most common, would no doubt afford good protection to the stock.

Norway Lobster.

Distribution and Fishery.

The salinity in the southernmost region of our inner waters, where the Norway lobster occurs, is about 29—30‰. The range of depth is from 30 to 200 metres; below 240 metres it was not found during our investigations. The tiny fry (larvae at the younger schizopod stage) are carried outside the habitat of the adult and are found also in the Belt Sea (E. M. Poulsen, 1946).

The fishery is carried out by means of trawl, the mesh width of the bag is generally 52 mm. at the mouth and 34 mm. in the cod-end. The trawls used for the fishery differ to some extent in that not only trawls designed especially for Norway lobster are used, but also designed for other species, for example, the haddock and the deep sea prawn.

The following figures give the annual quantity of Norway lobster caught in our various waters as a mean of the years 1946 and 1947.

Skagerak 22 tons, Kattegat 1055 tons, and the Belts 1 ton, total 1078 tons.

The distribution of the catches throughout the year is shown in the following table (means in tons, 1946 and 47) for Skagen + Frederikshavn, the two places where by far the largest catches are landed:

Jan.	3	July	147
Febr.	2	Aug.	74
March	9	Sept.	43
April	2	Oct.	35
May	60	Nov.	9
June	139	Dec.	9

The fishery is carried on throughout the year, but by far the largest catches are made during summer and early autumn.

Variations in the Yield of the Fishery.

Up to the year 1930 the fishery was unimportant and the catches so low, that they were not given in the statistics ("Fiskeri-Beretning").

Since 1931 it has increased very rapidly (Table 2); in recent years the yearly catch has varied between 600 and 1000 tons with a value of $1^1/_4$—2 million Danish kroner.

A steady increase brought the yield up to 800 tons in 1939. In the following years there was an extremely rapid decline: in 1940 the yield was only 62 tons and in 1941 it was as low as 49 tons; then it rose again to a maximum of 1113 tons in 1946; in 1948 a new decrease occurred, the catch of that year being 650 tons only.

In the above-cited paper (1946) I have tried to show that the great decline in the yield during 1940—42 was due not only to the restrictions of the fishery caused by the war, but also to the effects on the stock of the low temperatures of the sea water during these years.

Size and Proportion of Males to Females (non-berried and berried).

In Table 3 is shown the length of the individuals in the samples investigated. Of a total of 2221 specimens the biggest were two males of 24 and 25 cm. respectively; the biggest females were 20 cm. long.

The table is composed partly of samples taken during the experimental fishing with the eel-tog with meshes in the cod-end of only 14 mm. from knot to knot, and partly of samples from the commercial trawl fishery with meshes in the cod-end of about 34 mm. from knot to knot.

When we consider only the samples caught in the small-meshed eel-tog, the mean size of the males is 15·2 cm. and of the females 12·2 cm. In the commercial

Table 2. Total yield in tons and 1000 Kr. of the Danish fishery for Norway lobster.

Year	Tons	1000 Kr.
1931	10	4
1932	55	24
1933	100	25
1934	280	84
1935	400	144
1936	640	371
1937	510	262
1938	674	354
1939	804	405
1940	62	67
1941	49	93
1942	105	319
1943	297	695
1944	438	1210
1945	787	1592
1946	1113	1925
1947	1040	2073
1948	650	1275

Table 3.

Total length (from the point of the rostrum to the hind edge of the telson) of Norway lobster caught in the eastern Skagerak and the northern Kattegat during the commercial fishery in the years 1935/39 and 1946/48 and during experimental fishing with the eeltog in 1935/38 and 1948.

	1935—1939 commercial trawl			1946—1948 commercial trawl			1935—1938 eeltog			1948 eeltog		
		♀			♀			♀			♀	
cm.	♂	not berried	berried	♂	not berried	berried	♂	not berried	berried	♂	not berried	berried
8	—	—	—	—	—	—	—	5	—	3	1	—
9	5	2	—	1	—	—	3	7	—	—	—	—
10	6	4	—	1	1	—	14	16	—	1	2	—
11	11	15	—	5	5	—	26	27	—	2	—	1
12	26	7	3	12	15	—	35	27	—	7	2	—
13	22	8	3	18	20	—	50	27	—	6	1	—
14	48	7	3	44	31	—	61	19	1	4	1	—
15	74	12	7	73	22	1	59	10	—	1	—	—
16	90	34	20	175	20	—	38	9	—	3	—	—
17	72	37	9	158	3	—	35	1	—	3	—	—
18	64	14	2	166	1	—	42	—	—	3	—	—
19	29	1	1	104	—	—	22	—	—	3	—	
20	19	1	—	39	—	—	13	—	—	1	—	—
21	12	—	—	6	—	—	9	—	—	3	—	—
22	7	—	—	3	—	—	7	—	—	1	—	—
23	4	—	—	—	—	—	4	—	—	—	—	—
24	—	—	—	—	—	—	1	—	—	—	—	—
25	—	—	—	—	—	—	1	—	—	—	—	—
No.	489	142	48	805	118	1	420	148	1	41	7	1
Mean l.	16·0	15·2	15·6	16·9	14·1	15·0	15·2	12·3	14·0	15·2	11·3	11·0
Mean l. of spec. > 16..	18·1	17·0	16·2	17·5	16·2	16·2	18·0	16·1	—	18·5	—	—

samples taken with large-meshed trawls the mean size of the males is 16·7 cm. and of the females 14·7 cm.

The berried females measure from 11 to 19 cm. with a mean of 15·5 cm.

The present Danish size limit is 16 cm. Of the 51 berried females 19 specimens, or 37 %, are below 16 cm. and thus protected by the size limit.

In the catches the males predominate:

	Eel-tog		Commercial Trawl		Total
	1935–38	1948	1935–39	1946–48	
Males %	73	84	72	87	79
Females %	26	16	28	13	21

The number of the males thus amounts to 4 times the number of the females. It could be assumed that this is caused by the selective effect of the gears, a larger proportion of the bigger males than of the smaller females being retained; the fact, however, that the proportion of males to females is very nearly the same in the small-meshed eel-tog catches as in those of the large-meshed trawls, shows that this cannot be the case. The cause is no doubt that the females, to a greater extent than the males, lead a sheltered life in their holes in the mud. The same obviously is the case—and even to a greater degree—with the berried females, the percentage of the berried females to the total number of females in the samples being as low as only 11.

The fishery for Norway lobster in the open sea of the northern Kattegat and the eastern Skagerak has been carried out since 1931 and with considerable strength since 1933—34.

By means of the comparison of measured samples from the commercial fishery, as well as from the experimental fishery, it is possible to ascertain if the size of the individuals has altered during the years, and particularly so since we have measurements from two periods, 1935—39 and 1946—48 (see Table 3).

The following mean sizes were found in the material from the eel-tog (No. of specimens in brackets):

	1935/36	1948
Males total	15·2 (420)	15·2 (41)
Males > 16 cm.	18·2 (172)	18·5 (17)
Females total	12·3 (149)	11·3 (8)
Females > 16 cm.	16·1 (10)	—

Here the mean size of the males has not changed: there is, however, a small rise (0·3 cm.) in the size of males above the size limit (16 cm.). For the females the size has decreased about 1 cm. The numbers of specimens from 1948 are however so small that the figures can scarcely be relied upon.

The following mean sizes were found for the material caught with the commercial trawl, No. of specimens in brackets:

	1935/39	1946/48
Males total	16·0 (489)	16·9 (805)
Males > 16 cm	18·1 (297)	17·5 (651)
Females total	15·3 (190)	14·2 (119)
Females > 16 cm	16·7 (119)	16·2 (24)

For all the males the mean size is somewhat higher in 1946/48 than in 1935/39, whereas the females are smaller in 1946/48 than in 1935/39. There is, however, reason to suppose that the mesh-width of the trawls has altered somewhat during the years in adaptation to the size limit. Therefore, a truer picture of possible variations in the mean size is gained by comparing the mean sizes of the individuals above the size limit (16 cm.). Such a comparison shows a small decrease in size 0·6 cm. for the males and 0·5 cm. for the females.

Propagation.

As already mentioned, berried females are rare in the samples. Out of 466 females only 51, or 11 % were berried. The smallest berried female measured 11 cm. If we calculate the percentage of berried females from all females above 11 cm., this percentage is still low, only 12 %. Observations on the seasonal occurrence of the berried females show that the eggs are shed during summer and autumn, and that the larvae hatch during spring and summer. This is in accordance with the fact that pelagic larvae were caught with ring-trawl in our waters from April to October. When we consider the much shorter period during which pelagic larvae of the true lobster can be found, this is rather astonishing. It is further of interest to note the large variations in the temperature of the water at the depths (20—30 m.) at which the larvae were found during this period; at Anholt Knob L.V. the mean temperature (28 m.) is in April 4·3° and in September 13·1°. Thus the pelagic fry is able to sustain temperatures from 4° to 13°. However, this is in good accordance with the very wide distribution of the Norway lobster, from the border of the Arctic Sea (Iceland—northern Norway) to the subtropical waters of Morocco.

Protection.

The Danish Fisheries Act fixes a minimum size of 16 cm. for Norway lobster measured from the point of the rostrum to the hind edge of the telson. As the females propagate down to a size of 11—12 cm. a large proportion, ca. 37 %, of the mature females are protected by this size limit. As the females only rarely attain a size bigger than 18 cm., the large bulk of the catches, 88 % according to the analyses, is made up of males.

The Prawn.

Distribution and Fishery.

The prawn (*Leander adspersus*) is an inhabitant of the shallow coastal waters and occurs especially in places with a rich vegetation of eelgrass or larger algae, as in bays and fjords where the conditions are best for a dense vegetation. The prawn is found in some bays and fjords of our North Sea coast and in most places along the coasts inside the Skaw.

The fishery is carried out mainly by means of weels, and to a less degree with the hand push-net; in a few places small-meshed seines are used. The largest catches are made in spring and summer; in the winter, when the prawns stay in somewhat deeper water, the catch is smaller.

Prawn fishing is not carried out in the North Sea and the Skagerak; in the other waters the mean yearly catch for 1946 and 47 was as follows:

Kattegat	13	tons
Sound	3	—
Belts	213	—
Western Baltic	30	—
Baltic proper	6	—
Limfjord	5	—
	270	tons, total value 1·6 million kr.

Thus it is the Belt Sea, with its many sheltered bays and fjords, which yields by far the largest catches.

Variations in the Yield of the Fishery.

The prawn fishery is an old one in Danish waters. About the middle of the 19th century it was carried out, at any rate in the Limfjord, by means of a "glib", a hand push-net. When the collection of fisheries statistics began in 1885, the prawn fishery was already as big as it has been in the best years since then. The fishery was carried out by means of hand push-net, weels and small seines, i. e., the same gears as used now.

Great variations in yield have occurred since that time (Figure 3); the smallest yield was in 1922, only 24 tons, the best in 1948, 364 tons. The fact that the main fishery takes place during the same period as the spawning of the eggs and the hatching of the larvae, has, through most of the period, caused great anxiety as to the fate of the stock of prawns. Whenever the yield decreased, the question of overfishing was raised. (Th. Mortensen, 1897 and C. G. Joh. Petersen, 1909). However, in later years the catch has been as high as at the beginning of the prawn fishery in all Danish waters except the Limfjord, where the yield has decreased steadily for the last 20 years.

The variations in the yield since 1885 consisted roughly of a decrease from a maximum of about 300 tons in the eighties to a minimum of only some 30 tons in the twenties and then again a rise up to about

300 tons during recent years. But very great fluctuations from year to year have occurred during the period, and these fluctuations seem to be caused at least to some extent by variations in the winter temperature, a low temperature resulting in a small fishery. In Figure 3 the colder winters are shown with arrows. It is obvious that bad catches were obtained in the years with a cold winter, for example, the years 1888, 1922 and 1924, and 1940—42, or just after such years. No doubt a cold winter kills a lot of prawns, thus causing a decrease in the stock that partly affects the fishery of the same year and partly diminishes the number of prawns spawning. As a result of this the effect of a cold winter may last for a couple of years, as shown, for example, by the only gradual increase of the stock after the severe ice winters 1940—42. In this connexion it must be mentioned that according to A. C. Johansen (1929) considerable quantities of dead prawns were observed in our waters just after the severe winter of 1929.

Protection.

No size limits or closed seasons are introduced in Danish waters for the protection of the prawn. However, the minimum size of the meshes in the prawn weel is fixed at 16 mm. from knot to knot.

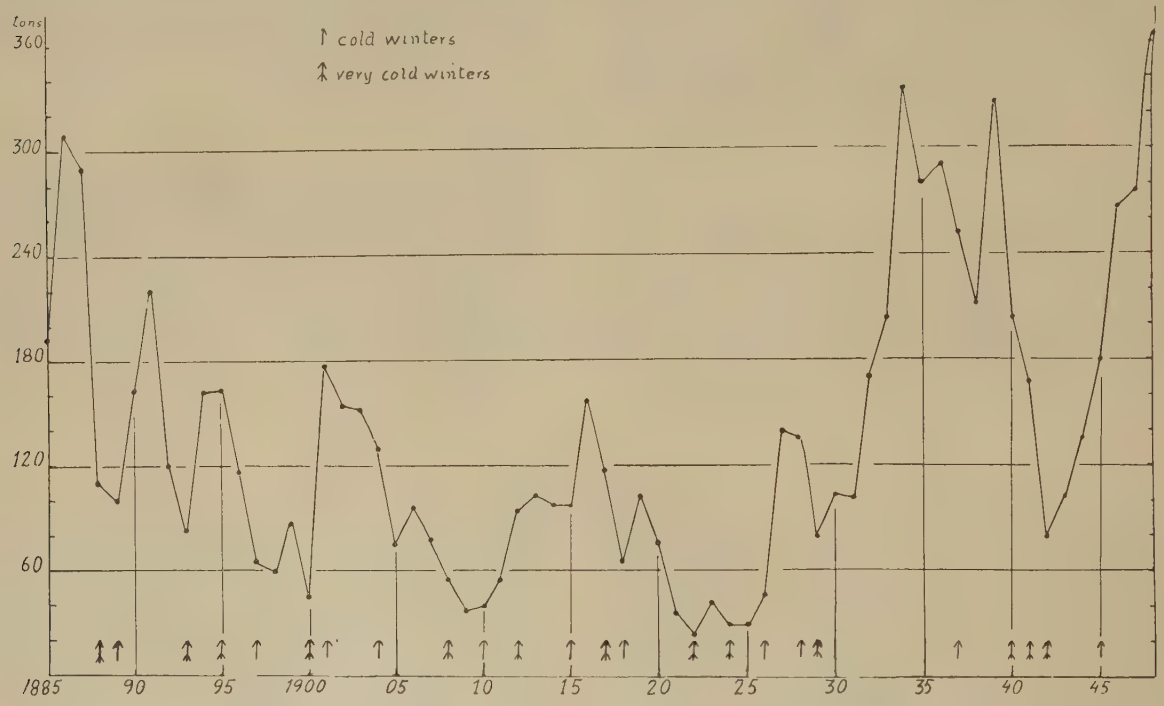

Fig. 3. Total yield of the fishery for prawn (*Leander adspersus*) in Danish waters 1885—1948.
The arrows indicate cold winters (January—March).

Deep Sea Prawn.

Distribution and Fishery.

In the Danish seas the deep sea prawn occurs in the north-eastern part of the North Sea, in the Skagerak and in the north-eastern Kattegat.

During the investigations made by the Danish Biological Station deep sea prawns were found at depths between 60 and 650 m.; the largest catches being made between 150 and 400 m. The young are found in considerably shallower water, in several cases even inside the 25 m. line. In the places where the adults are taken the temperature of the bottom water ranges between 5·1° and 9·5° C., being in most cases between 5° and 7° C. In the same places the salinity of the bottom water is between 34 and 35·7 $^0/_{00}$. The fry (schizopod stages) are found down to a salinity of 32 $^0/_{00}$ and at temperatures as high as 13°—14° C.

The fishing grounds are situated N., NW. and NE. of Skagen at a depth of 150—250 m. During later years the fishery has extended further westwards in the Skagerak along the 200 m. line. The prawns are caught exclusively with the trawl. The size of the gear varies somewhat; generally the foot rope is about 45 m. and the bag about 15 m. long. The mesh width in the wings is 40 mm., in the middle part of the trawl 25 mm., and in the bag 18 mm. from knot to knot.

The fishery takes place in day time and the best hauls are made in the middle of the day and in bright weather, obviously because the prawns under such conditions are crowded on the bottom where the trawl is towed.

The fishery is a typical seasonal one being carried out mainly during the summer months as can be seen from the following figures giving the mean monthly catch from Skagen for the years 1946 and 47:

Jan.	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0·5	0·2	18	34	88	44	62	48	20	15	5	5

Yearly Variations in the Yield of the Fishery.

The yield of the Danish fishery shows a very rapid rise since the beginning of the fishery in 1931 (Table 4). In 1931 the yield was only 28 tons; until 1936 it gradually rose to 243 tons; a small decline occurred in 1937. Later a new increase took place, and in 1943 the yield was 587 tons. During the years 1944—46 the catch again was smaller, about 270—280 tons. Recently, however, it has increased again, and in 1948 the yield was 468 tons. The value of the catch in that year was 2,714,000 kroner.

Table 4. Catch in tons and Kr. of deep sea prawns in Danish waters.

Year	Tons	1000 Kr.
1931	28	25
1932	55	46
1933	38	32
1934	168	145
1935	172	114
1936	243	203
1937	157	159
1938	222	238
1939	371	294
1940	219	247
1941	293	404
1942	390	1421
1943	587	1268
1944	274	1091
1945	267	1657
1946	288	1687
1947	387	1769
1948	468	2714

Reproduction, Size and Growth.

Thanks to the comprehensive investigations by Hjort and Ruud an excellent knowledge of the biology of the deep sea prawn has been gained, and I shall here only give some few observations from the area in the open Skagerak north of Skagen, where the Danish fishery takes place. The observations up to 1940 were dealt with in a previous paper (Erik M. Poulsen, 1946).

In Table 5 is shown the length distribution of the males and females separately. The mean length of the males is about 10 cm. (total length, i. e. the rostrum included), with individuals ranging from ca. 8 to ca. 13 cm., and that of the females is about 13.5 cm., ranging from $10^1/_2$ to $15^1/_2$ cm. Transitionary stages between males and females were found in a small sample from January but not in any of the samples from July to October.

Table 6 gives the measurements of males and females taken together. The mean total length in the samples caught by the eel-tog, which has a mesh width in the bag of 14 mm., is in the various samples between 9 and $9^1/_2$ cm., and for the commercial trawl (mesh width ca. 18—22 mm.) between $10^1/_2$ and $11^1/_2$ cm. A lot of the smaller prawns are therefore saved by the commercial trawl.

The material at hand shows a smaller decrease from 1934 to 1949 in the individual size of the prawns caught. The mean size of the prawns caught in 1934 (11·8 cm.) was nearly the same as the size of the prawns in the samples from 1947—49 (10·3—11·4).

Females carrying eggs have been found in samples taken in April and in October, but not in any of the

Table 5. Measurements of length (from the anterior edge of the eyes to the point of the telson) of deep sea prawns caught in the Skagerak.

	23 M. N.$^1/_2$E. of Skagen, 203 m. 23/8 1938 eel-tog		70 M. W. of Skagen, 250 m. 1/10 1946 comm. trawl		67 M. W.$^1/_4$N. of Skagen. 300 m. 17/7 1947 comm. trawl.		70 M. W.$^1/_4$N. of Skagen, 250 m. 14/8 1947 comm. trawl		35 M. NW. of Skagen, 250 m. 17/9 1947 comm. trawl		14 M. N. of Skagen, 200 m. 25–28/8 1948 comm. trawl	
cm.	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
6	15	—	7	—	—	—	11	—	4	—	5	—
7	50	—	67	—	—	—	50	—	71	—	60	—
8	17	8	34	1	14	1	71	3	130	14	27	5
9	—	23	14	5	7	11	16	52	81	67	4	11
10	—	7	1	23	—	30	—	15	—	96	—	27
11	—	—	—	47	—	29	—	—	—	45	—	3
12	—	—	—	8	—	7	—	—	—	9	—	—
Total...	82	38	123	84	21	78	148	70	286	231	96	46
Mean length	7·0	9·0	7·5	10·7	8·3	10·4	7·6	9·2	8·0	10·1	7·3	9·6
Mean total length	9·1	11·7	9·8	13·9	10·8	13·5	9·9	12·0	10·4	13·1	9·5	12·5

Table 6.

Measurements of length (from the anterior edge of the eyes to the point of the telson) of deep sea prawns from Skagerak caught with the eel-tog (E.) and with the commercial trawl (Tr.).

cm.	13 M. N. b. E. of Skagen L.V. 207 m. 13/7 1934 E.	28 M. NW. of Skagen L. 227 m. 19/8 1935 E.	26 M. N. b. W. of Skagen L. 198 m. 7/7 1936 E.	25 M. NW. of Skagen L.V. 210 m. 27/8 1937 E.	23 M. N. ½ E. of Skagen L. 203 m. 23/8 1938 E.	14 M. N. b. E. of Skagen 200 m. 13/7 1934 Tr.	70 M. W. of Skagen 250 m. 1/10 1946 Tr.	35–70 M. NW. of Skagen 250–300 m. 7/9 1947 Tr.	15 M. N. of Skagen 200 m. Aug. 1948 Tr.	20 M. N. of Skagen 220 m. 15/7 1949 Tr.
3	—	—	—	—	—	—	—	—	} 26	—
4	—	1	—	—	—	—	—	—		—
5	11	4	—	1	4	—	—	—	4	1
6	59	39	40	29	80	—	7	15	363	30
7	107	115	126	93	83	2	67	121	1684	81
8	10	30	23	8	37	20	35	233	863	21
9	13	32	28	12	26	43	19	234	664	27
10	6	8	10	8	8	29	24	141	447	17
11	2	—	1	—	—	3	47	74	121	15
12	—	—	—	—	—	1	8	16	11	1
Total ...	208	228	228	151	238	98	207	834	4183	193
Mean length ..	6·9	7·3	7·3	7·2	7·1	9·1	8·8	8·8	7·9[1])	8·1
Mean total length ..	9·0	9·5	9·5	9·4	9·2	11·8	11·4	11·4	10·3	10·5

[1]) The 26 small not included.

many samples from the months June to September, which shows that the eggs are laid in the autumn and that the larvae hatch in the spring.

Protection.

No measures for the protection of the deep sea prawn have been introduced.

Danish fishing experiments in the Skagerak in 1948/49 have shown that a considerable number of the smaller prawns are saved when larger meshes are used in the bag, and further that the mean size (total length) of the prawns caught is nearly identical whatever the bag is closed according to the Norwegian method (a sowing) or to the Danish closing device (a simple knot):

	18 mm. meshes	22 mm. meshes
Norwegian closing.....	10·3 cm.	11·7 cm.
Danish closing.....	10·3 cm.	12·1 cm.

A protection of some value is found, however, in the seasonal distribution of the fishery, in that the fishery is only small in the months from October to April, i. e., in that part of the year when the females are egg-carrying.

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17.

Some Problems in the Fishery for Deep Sea Prawns.

By

Birger Rasmussen

The biology of the deep sea prawn has been studied by many scientists, e. g. Wollebæk (1903), Wilhelm Bjørk (1911), Alfreda Berkely from British Columbia (1930), Leopoldseder (1934), Jägersten (1936). In 1938 Professor Johan Hjort and Johan T. Ruud published a comprehensive treatise on the deep sea prawn fishery in Norway.

According to Hjort and Ruud the prawn in the Oslo Fjord has a comparatively rapid growth. The berried females hatch their young in spring, and the size of the young is 5—6 mm. When $^1/_2$ year old they measure 50 mm., 1 year old 78 mm. and $1^1/_2$ years old 93 mm. They are now functioning males. A year later the prawn has grown to 120 mm., and they are spawning as females in the autumn when $2^1/_2$ years old.

When working on the prawn material from Spitsbergen it became apparent that we had to revise any conception that the growth and development of the deep sea prawn was largely similar in all areas of its distribution. The first thing noticed was that this arctic prawn population spawned 2 months earlier and that the eggs hatched 2 months later than was the case in the Oslo Fjord. The growth-rate proved to be extremely slow in comparison to that in the Oslo Fjord. Another feature worth noticing was that the size of the prawn when becoming active males and females was nearly the same in both localities in spite of the difference in age.

In the Mist Fjord in northern Norway a prawn population has been found which obviously constituted an intermediary growth type between that of Spitsbergen and that in the Oslo Fjord. The prawns in the Mist Fjord become ovigerous females at a later age than in the Oslo Fjord; but earlier than in Spitsbergen waters. Although the size of the prawns when reaching maturity as males and females respectively was about the same in all these localities, the age when reaching these stages varied.

We have here an example of variability in growth and maturing in one and same species quite noteworthy in marine biology. If we look for an explanation of this phenomenon it is quite natural to think of the environment as an influencing factor, e. g., temperature, salinity, food supply and the topographical features of the sea bottom. In this connexion some observations taken on these prawning grounds may be of interest.

The Mist Fjord has a bar at its entrance with a saddle depth of 50 m. The warm Atlantic water outside the fjord cannot enter, and the bottom here is covered with coastal water of about 3·5—4·0° C.

At Spitsbergen we find temperatures between 0—3° C. in summer on the prawning grounds, but we may also find temperatures below 0° C. In other words, in the north colder surroundings apparently cause a slow growth and maturation. In the Oslo Fjord the temperature varies between 6—8° C. during the year. We may say that a prawn population from a locality in northern waters has a slower rate of renewal and recuperation than is the case on more southerly grounds, and that a northerly population is unlikely to stand the same intensive fishery and taxation as a southerly one.

In western and southern Norway prawn populations have been found which show that all individuals belonging to a year-class do not become ovigerous females at the same age, and that the sexual development is closely connected with the local rate of growth. As an example we may take the prawns from the Torungen ground in the Skagerak area. Figure 1 shows the growth and development of the prawn from this locality. The height of the columns gives the number of individuals expressed as percentages of the total sample. The numbers at the bottom express the total length in mm. after conversion of the original measurements.

On the bottom left we have $^1/_2$-year-old prawns measuring 52 mm. They grow rather fast, and 1 year later they measure on the average about 89 mm. They are now active males. But there are some few individuals which do not develop in the usual way, but instead become berried females of $1^1/_2$ years old. On the average we may say that it is only about 1% of the year-class which behaves in this way. These young females we find on the right hand side of the age-group. In other words, it seems to be the larger in-

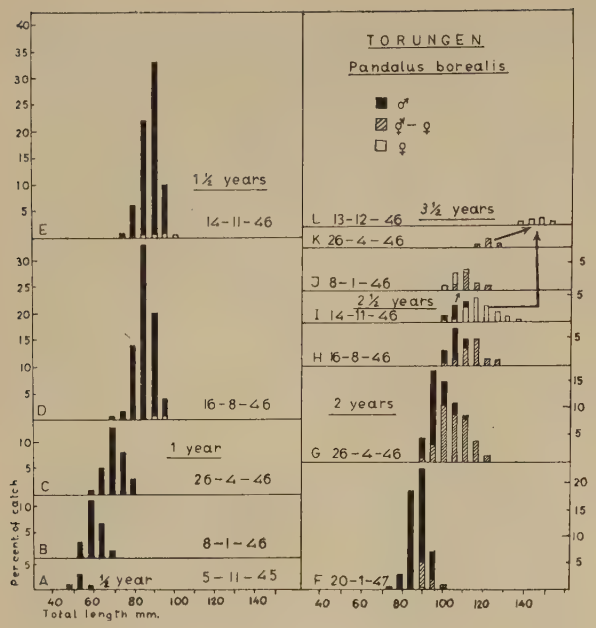

Figure 1.

dividuals of the age-group which have the tendency to become females at an early stage.

Two months after spawning we find that the males behave rather curiously. In January the male group splits into 2 sections, one retaining the male characters, the other changing into females. This is still more pronounced in April. It is again the largest individuals of the age-group which become females, while the smaller ones remain males. The female section becomes ovigerous when $2^1/_2$ years old at a size of 120 mm., the same length as found by HJORT and RUUD for the prawn in the Oslo Fjord. The rest of the age-group function as males for the second time in their life. We may say that probably between 60—70% of a year-class become females at this age, while 30—40% remain males.

After functioning as males for the second time these latter individuals enter the transitional stages and become females. They seem to have a rather rapid growth after leaving the male stage. They become berried females for the first time when $3^1/_2$ years old, at approximately the same size as the second-time female spawners.

The Composition of the Catches.

As regards the age composition (Figure 2) we find 4 year-classes represented in December 1945. During the year 1946 the number of oldest and largest prawns decreases, the 1942-class disappearing completely. At the same time the youngest year-class (1945) rapidly rises to dominating strength. This year-class reaches its maximum strength in the catches when $1^1/_2$ years old when it constitutes about 70% of the catch. In January 1947 the 1945-class begins to lose its dominancy and a new year-class (1946) enters into the catches.

The sex composition varies with the season. Without going into details, the figure shows that the major part of the catches is composed of males and youngs, while the most valuable part of the catch from a commercial point of view—the large females—are the least numerous.

As regards the rate of mortality this question has been treated in an earlier paper (Ann. Biol. 1947). On the Torungen ground the prawns are most heavily exploited when about $1^1/_2$ years of age, while further north, on the Vigrafjord ground in western Norway, the point of maximum exploitation is $1^3/_4$ years. In the latter locality the prawns have a slower growth-rate. In both localities a year-class is no longer of any significance after an age of 3 years. We may say that the age of maximum exploitation of a prawn population is determined by the local rate of growth and by the selective action of the prawn trawl.

In the Torungen material we find that the mortality of a year-class during the 1 year from the age of $1^1/_2$ to $2^1/_2$ years is about 67%. On a ground on the west coast of Norway where the prawn has a similar development, the mortality within the same space of time was found to be about 68%. The age from $1^1/_2$ to $2^1/_2$ years is apparently the critical period when the prawns in these particular areas show the most rapid decline.

In the commercial fishery the prawns are sorted according to size into 2 categories, small and large.

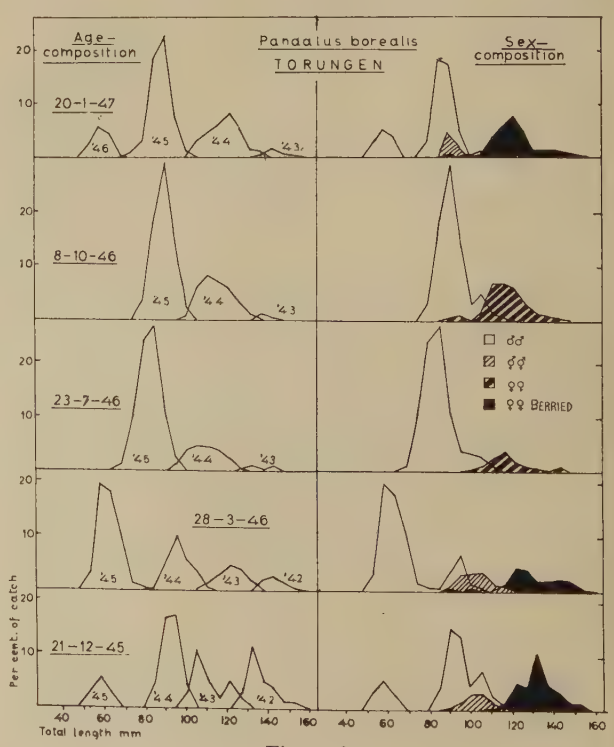

Figure 2.

It is practically only large prawns which form the basis of the Norwegian export trade. The sorting of prawns is done by hand or by the aid of a sieve. On the average we may say that the sieve sorts out as small prawns those below 10 cm. (according to experiments carried out by HJORT and RUUD). While fishing in inshore waters, the undersized prawns may be sold to canning factories or sold for bait. On distant grounds, as in the central Skagerak, the small prawns will be of little value. During and after the war the price of small prawns has been increasing.

In Figure 3 is shown the percentage of small prawns in catches from Torungen, and, for comparison, catches from the Oslo Fjord in identical months. The figures for Torungen show that during the whole year, but mainly in spring and summer, considerable quantities of valueless prawns are destroyed. The catches in the Oslo Fjord have by comparison yielded very few small prawns. The two fishermen were using identical trawls with the same mesh-width, but the fisherman in the Oslo Fjord had tied the trawl's cod-end in a different manner.

We may assume that a great part of the escaping small prawns are sifted through the meshes of the cod-end. How many prawns escape, and of what size, depends to a certain extent on the mesh-size in the cod-end. But at the same time it is equally, if not more, important how the meshes are distended during the trawling operation. Generally, when fishing, the cod-end is pursed together at the centre end or tied up with a knot. By this procedure the net will lie in folds, the meshes cannot distend properly, with the result that the small prawns escape only with difficulty. This is the method used on the Torungen grounds. In the Oslo Fjord the cod-end is laced together and tied up in one corner permitting the meshes and the net to be fully extended when fishing.

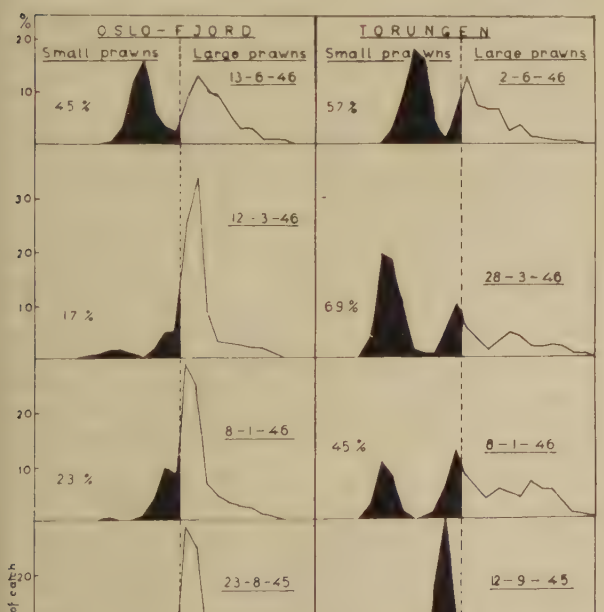

Figure 3.

The difference in the composition of the catches as shown in Figure 3 may most probably be attributed to the different methods of tying up the cod-end. The catch of small and unmarketable prawns can be very large and presumably prove a heavy drain on the prawn population on limited prawning grounds.

In the international co-operation on fisheries problems it has been shown that a saving of small fish can be brought about by means of mesh regulations. This is based on the experience that a great number of small fish escape from the trawl without reducing the catch of large and edible fish in any great degree. A similar solution in the case of the prawn trawl would seem obvious.

HJORT and RUUD have more fully investigated the problem to find a mesh size which does not give much smaller catches of large prawns while at the same time the undersized prawns have a better opportunity to escape. But it is not only the mesh which determines the size of prawns in the catch. The relative quantity of large and small prawns on the ground, the size of the stock, and—as we have seen—the way of tying up the cod-end, all play a part. BJERKAN (1939) indicates the possible use of a special fishnet flapper in the cod-end as possible means of saving the small prawns.

The term often used for mesh size, i. e., a certain number of knots per metre, yard or foot is an inexact way of stating the effective size of the mesh. The effective mesh size is not determined by the number of knots, but by the thickness of the twine, the quality and the shrinking ability of the material used.

Besides the regulation of the mesh size, the question of a closed season has been mentioned. From a biological point of view a closed season would be of great benefit if it was made effective somewhere between January and April. In January—February we get a comparative high percentage of small soft-shelled males and transitionals. In March—April the prawn eggs are ready for hatching in the females. On the other hand, during the winter the large prawns are of excellent quality, having high prices for export and inland consumption.

The question of protecting the deep sea prawn and other shellfish in the Skagerak area has been taken up by the International Council for the Exploration of the Sea. The Transition Area Committee has recommended that the countries interested in the deep sea prawn fishery in the Skagerak adopt identical measures in regard to mesh size and manner of tying up the cod-end of the prawn trawl.

18.

Cancer pagurus L.

Informations sur l'Intensité de la Pêche et les Migrations de l'Espèce près des Côtes de France.

Par

P. Desbrosses

Le crabe dormeur, *Cancer pagurus* L. ne fait pas l'objet d'une pêche spéciale sur les côtes de France; de Mai à Octobre, il est capturé dans les casiers à homards, dans les filets à langoustes, dans les filets à rougets-barbets, dans les trémails etc. . .; en hiver il est pêché occasionnellement au chalut.

Des crabes venant de muer, et sans valeur marchande sont souvent marqués au couteau par les pêcheurs (qui inscrivent le nom du bateau ou le port d'attache et le numéro d'immatriculation du bateau de pêche, ainsi que la date de capture); puis ils sont rejetés à la mer, et souvent repêchés. Ces reprises fournissent des indications sur les déplacements et l'intensité des captures de l'espèce.

I. Ainsi un crabe pêché le 9. Juillet 1935 par 47°20′ L.N., à l'ouest de Belle-Ile par 50 m. de fond, a été rejeté à la mer après avoir reçu sur sa carapace l'inscription: "Lindbergh G.V. 5604" (nom, port et n° d'immatriculation du bateau).

Il fut repris 11 mois plus tard: le 10 Juin 1936 au sud de Belle-Ile (sud de la Pointe de l'Echelle) par 42 m. de fond, à 11 milles dans le sud-est du premier point. L'équipage ajouta sous l'inscription précédente "Vu" et libéra le crabe.

Cinq jours plus tard: le 15 Juin, le même crabe se fit prendre à nouveau dans les mêmes parages par le même navire; les pêcheurs ajoutèrent au couteau sur le dos de la carapace, à côté de "Vu" le numéro d'immatriculation du bateau "4816" et le libérèrent une 3ème fois.

Un mois après, le 15 Juillet, le crabe marqué était repris dans le casier d'un autre équipage, à 3 milles environ dans le sud-est du point précédent, par 45 m. de fond.

L'exemplaire me fut alors apporté au laboratoire de Lorient. C'était un mâle mesurant 203 mm. de largeur de carapace et pesant 1,438 grammes. Son déplacement total, en ligne droite, a été de 15 milles en un an, en direction du sud-est. Si l'on tient compte de sa migration probable à l'automne vers le large et de son retour au printemps vers l'isobathe des 50 m., on doit admettre un déplacement beaucoup plus important.

Le fait le plus remarquable est que ce crabe ait été pêché 4 fois en un an (durant les seuls mois de Juin et Juillet), et à l'aide d'un engin passif: le casier boëtté.

II. Dans les mêmes parages, 3 captures successives d'un *Cancer pagurus*, mâle lui aussi, pesant 1,850 grammes (lors de la dernière capture) ont été signalées par M. Fontaine[1]).

Ses déplacements ont été, la première année, de 16 milles vers le sud-est, la 2ème année de 14 milles vers l'est. La migration, de 1935 à 1936, a été de même direction et de même amplitude (à 1 mille près) que celle de notre exemplaire (marqué 2 mois plus tôt): les 2 *Cancer pagurus* pêchés au nord-ouest de Belle-Ile en 1935 furent repris en 1936 au sud-est de la même île.

D'autres observations seraient nécessaires pour qu'on puisse en tirer des conclusions sur les migrations de l'espèce.

Le premier exemplaire a été pêché 4 fois en 12 mois, le second 3 fois en 23 mois: on peut conclure à une pêche intensive des crustacés à la côte sud de Bretagne.

III. Les autres captures de crabes marqués dans la même région n'apportent pas de renseignements précis sur l'importance de la pêche ni sur les migrations.

Citons un crabe porteur des insignes soviétiques marqué par un équipage de Concarneau et repris par un autre équipage Concarnois qui l'apporta en

[1]) Fontaine, M. 1937: A propos des migrations de crustacés. Bull. Soc. Zool. de France, T. 62, p. 417.

1933 à R. Legendre, sans indication des lieux de pêche[1]).

Un autre dormeur marqué le 16 Octobre 1936 à 10 milles à l'ouest de la Pointe de Penmarch et repris le 23 Juin 1937, 8 mois après, dans le Raz de Sein, 15 milles plus au nord; un dernier exemplaire pêché en Septembre 1936 à 5 milles au sud-ouest de Belle-Ile, et portant la marque d'un bateau de pêche (Virginie Hériot, sans date) qui fut libéré avec une seconde inscription sans qu'on en ait obtenu par la suite de nouvelles: il est probable que ce crabe n'a pas été pêché une troisième fois.

IV. En Manche, sur la côte nord du Finistère 7 *Cancer pagurus* ont été marqués en Mai 1936 par le patron du bateau "Le Diveza" de Roscoff et libérés près de l'île de Batz par 40 m. de fond.

Au mois de Juillet 1937, 2 avaient été repris: soit 3/10 en 14 mois.

C'est un nouvel exemple de l'intensité de la pêche aux crustacés, et spécialement aux *Cancer pagurus* L. près des côtes rocheuses de Bretagne sans que l'on puisse en conclure à un dépeuplement de l'espèce.

[1]) Boyer, J. 1933: Un crabe porteur des insignes soviétiques. La Nature, No. 2917, p. 462, 1 fig.

19.

Fluctuations in the Lobster (*Homarus vulgaris*) Population of the Scottish Coast.

By

H. J. Thomas

I. Introduction.

In 1948 a total of nearly 1,500,000 lobsters was landed in Scottish ports. Of this total Orkney landings were about 370,000, whilst the Hebrides contributed about 247,000 out of a total of about 587,000 for the whole of the west coast. The industry is of some economic importance in Scotland, especially so on the west coast where it is prosecuted by crofter fishermen and is one of their principal sources of income.

The annual landings of lobsters in Scotland during the period 1926 to 1936 fluctuated narrowly around 1,000,000 (Figure 1). In the same period the number of creels was maintained around 70,000. In 1937, 1938 and 1939 the same number of creels was maintained, but landings of lobsters decreased and in 1940 totalled only about 550,000. No record of the number of creels during the war years (1940—45 inclusive) is available, but the landings increased steadily from 1940 onwards and in 1946 reached about 1,500,000. In this year the number of creels was about 102,000. The lobster fishery was maintained at about this level, both in landings and in number of creels, during 1947 and 1948.

The above statistics may suggest at first sight, a falling off in the intensity of fishing during the war, with a resting of the stocks, in consequence of which the post-war fishery exceeds that of the pre-war period. It is notable however that the decrease in landings and in the catch of lobsters per creel starts to fall in 1937 and the minimum is reached in 1940. Furthermore landings for the east coast show a continued rise from 1930 onwards, with very little or no decrease corresponding to the 1940 minimum characteristic of the landings for the west coast and for Orkney, which determine the course outlined above for the entire Scottish lobster fishery (Figure 1). In view of this evidence it is doubtful if the fluctuations in the fishery can be attributable to the effects of the war. In any event, the increasing fishing, particularly on the east coast, whilst so far accompanied by an increasing yield, deserves close attention lest it should lead to a state of overfishing.

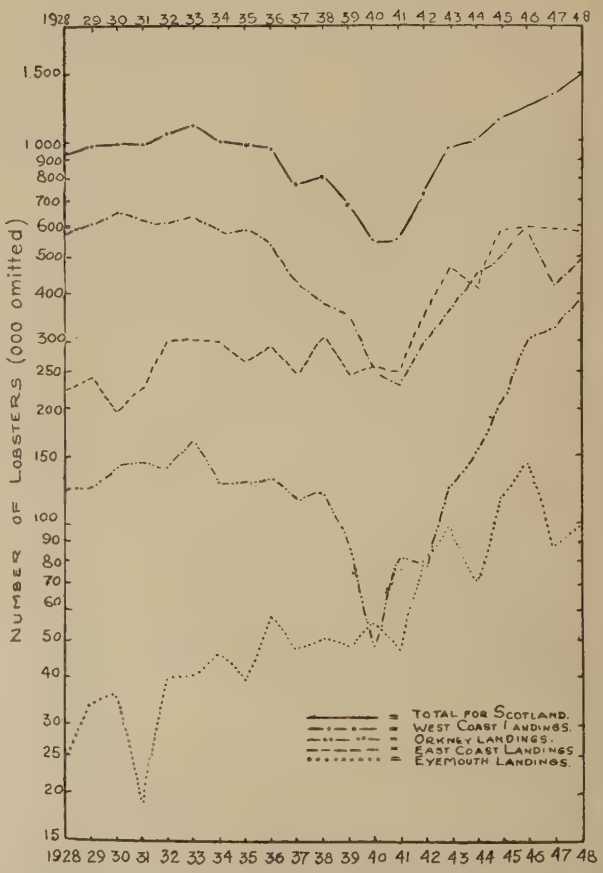

Fig. 1. Landings of lobsters in Scotland. The total number of lobsters (in thousands) landed annually, in the years 1928 to 1948 inclusive, is shown for the four sub-areas and for Scotland as a whole.

The landings for the Fishery District of Eyemouth closely follow those of the east coast and show the same steady rise throughout the war years (Figure 1).

In addition fluctuations in the number of creels since 1928 are roughly proportional for the east coast and the Eyemouth District which latter can therefore be taken as representative of the east coast as a whole. Detailed observations for the years 1931 to 1939 inclusive were made in the Eyemouth Fishery District, as well as in a number of other areas. The object of this paper is an analysis of these pre-war data, thereby to establish a basis for a fuller investigation of fluctuations in the Scottish lobster populations and fishery.

II. Methods.

During the years 1931 to 1938 inclusive a commercial lobster fisherman at Burnmouth and one at Rousay (Figure 2) were commissioned to measure, throughout the season, a sample of about 2,000 lobsters, to record the measurements to the nearest $^1/_4$″, and to classify the sample into males, non berried females and berried females.

In 1938 the (Ministry of Agriculture and Fisheries and the Fishery Board for Scotland) Interdepartmental Committee on Crabs and Lobsters instituted new investigations and devised a form for recording observations. In addition to information as to length, sex, etc., details of the number of creels lifted and the number of hours since creels were set were requested on this new form. Such observations were made during 1939 at six stations around the Scottish coast, Burnmouth, Rousay, Staffin, Sandside, Bernera and Tobermory (Figure 2)[1]).

The records for 1931 to 1938, of the fisherman observers, have the very serious limitation that in them there is no measure of the fishing effort involved in taking the sample. This information is included in the observations for 1939 but it is unfortunate that these more detailed records cover only one year.

The only sampling of lobsters which has been carried out is by means of creels. The accuracy of this mechanism as a sampling device is not known. The fishing efficiency of the creel, in respect of the smaller size-groups which it retains, will be less than for medium sized lobsters. Similarly the creel will fall off in fishing efficiency at the higher end of the scale where giant lobsters will be excluded by the dimensions of the eye.

The unit of fishing effort used, following the practice of Canadian workers (Wilder, 1947), is 100 creel-hauls. This has been preferred to a measure in term of creel-hours. Table I gives comparative figures for both methods of estimation in respect of the results from Burnmouth and Rousay. Were all periods of fishing of about the same duration the results of both series would be directly proportional but in practice this is not realized. The number of hours fishing is highly variable and in addition practices differ considerably in the various areas. For instance, on the east coast of Scotland large fleets of creels are left fishing for about 24 hours, whilst on the west coast of Lewis the practice is for a few creels, cast singly, to be fished continuously, each period of fishing being of the order of only $1^1/_2$ hours. All available evidence shows that creels cast for more than 24 hours are not catching a proportionately larger number than those cast for 24 hours or less (Table I). The catch for the shorter period tends in fact to exceed that for the longer. The use of creel-hauls gives a more accurate assessment of the fishing effort than does a measure in terms of creel-hours.

Fig. 2. Chart of Scotland. The position of six stations, at which lobster measuring was carried out in 1939, is shown.

Results drawn from a single source, such as a fisherman observer, will relate to creels of the same type throughout the period of the observations. In this case comparison of the catch per unit fishing effort, or of the percentage of each length group, reveals in the differences between one year and the next a similar change in the composition of the stock. It may be dangerous however to compare results of two observers too closely.

As no creel has the same fishing efficiency for all length-groups, the proportion of each group in the catch will seldom be the same as the proportion on the grounds. However, assuming that the fishing efficiencies of all commercial type creels are about the same for groups in the middle of the length range which is retained, the proportion of lobsters will tend to be the same on the grounds as in the catch within these groups.

On these assumptions it is possible, by comparison for each size-group of the catch per 100 creel-hauls,

[1]) Further information is available in the Sea Fisheries Statistical Tables of the Fishery Board for Scotland which are published annually (H. M. Stationery Office).

to measure the degree of fluctuation in the stock of marketable sized lobsters on a ground in different years and to compare the stocks of such lobsters in different years and areas.

Landings for the Fishery District of Eyemouth follow the landings for the east coast of Scotland very closely. Moreover, of the data available for this paper, the results for the Eyemouth District are most complete and exhibit a very pronounced fluctuation in length composition of the stock. For these reasons the Eyemouth results are used as a standard for the remainder of the observations.

III. Burnmouth.

The three creeks Burnmouth, Eyemouth and St. Abbs together constitute the Fishery District of Eyemouth. Of the shell fish landed, Burnmouth accounts for about 3/5ths (by value) of the total for the district, wo that variations in the lobster landings at Burnmsouth ill in large measure be applicable to the whole district.

Records of the size and sex of yearly samples each numbering about 2,000 are available for Burnmouth

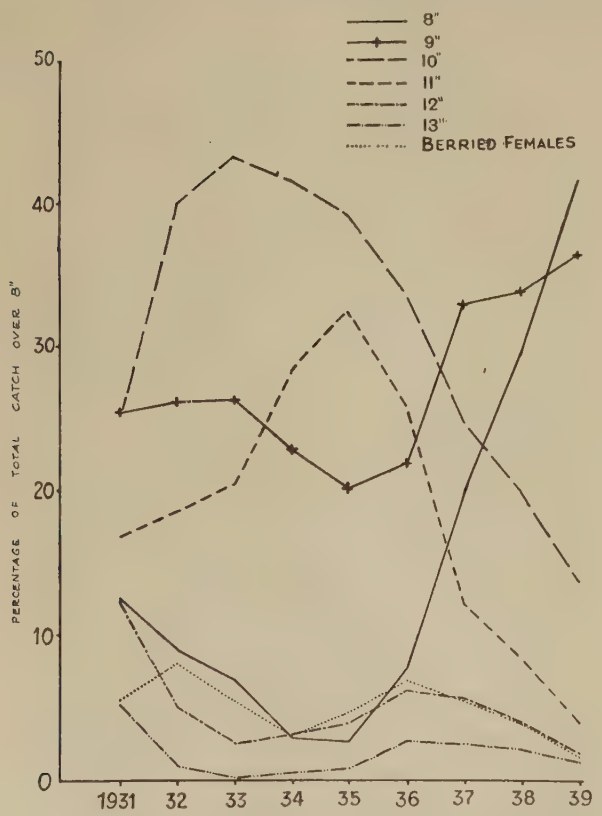

Fig. 3. Annual variation in the length compositions of lobsters landed at Burnmouth in each of the years 1931 to 1939 inclusive. The number of each 1 inch group, and of berried females (B ♀), is expressed as a percentage of the annual total of marketable sized lobsters.

Table I. Measurement of Fishing Effort.

Burnmouth.

	No. of Lobsters	Creel-hours	Creel-hauls	Lobsters 1000 Cr.-hrs	Lobsters 100 Cr.-hls	Lobsters 1000 Cr.-hrs	Lobsters 100 Cr.-hls
1939		18—30 hours Fishing					
May...	224	82,800	3,400	2·7	6·6		
June...	147	81,600	3,400	1·8	4·3		
July...	394	100,800	4,200	3·9	9·4		
Aug....	815	96,960	4,040	8·4	20·2		
Sept. ..	339	47,040	1,960	7·2	17·3		
Oct. ...	100	27,840	1,120	3·6	8·9		
		Over 30 hours Fishing				Overall	
May...	78	72,920	1,370	0·1	5·7	1·9	6·3
June...	57	65,800	1,200	0·9	4·7	1·4	4·4
July...	69	48,000	1,000	1·4	6·9	3·1	8·9
Aug....	185	48,000	1,000	3·9	18·5	6·9	19·8
Sept. ..	30	10,000	200	3·0	15·0	6·5	17·1
Oct. ...	22	17,600	320	1·2	6·9	2·7	8·5

Rousay.

1939		18—30 hours Fishing					
June...	84	6,700	268	12·5	31·3		
July...	233	18,215	752	12·8	31·0		
Aug....	216	16,140	669	13·4	32·3		
Sept. ..	174	15,500	620	11·2	28·1		
Oct. ...	85	7,500	300	11·3	28·3		
Nov....	36	3,600	144	10·0	25·0		
Dec....	70	8,550	342	8·2	20·5		
1940							
Jan....	51	6,750	270	7·6	18·9		
Febr. ..	44	6,750	270	6·5	16·3		
March .	106	10,500	420	10·1	25·2		
1939		Over 30 hours Fishing				Overall	
June...	24	4,282	95	5·6	25·3	9·8	29·8
July...	29	8,004	146	3·6	19·9	10·0	29·2
Aug....	25	5,750	115	4·3	21·7	11·0	30·7
Sept. ..	29	6,000	105	4·8	27·6	9·4	28·0
Oct. ...	19	6,750	120	2·8	15·8	7·3	24·8
Nov....	24	3,600	72	6·7	33·3	8·3	27·8
Dec....	38	9,750	180	3·9	21·1	5·9	20·1
1940							
Jan....	32	9,750	180	3·3	17·8	5·0	18·4
Febr. ..	26	7,500	150	3·5	17·3	4·6	16·7
March .	13	3,000	60	4·3	21·7	8·8	24·8

for 1931—38 inclusive. In addition a measure has been made for 1939 of the fishing effort involved in capture of the sample. Figure 3 depicts graphically the length composition of the stock, arranged in one-inch groups and expressed as a percentage of the total catch of marketable lobsters (length 8″ and over). The years 1932 and 1933 mark a considerable increase in the percentage of 10″ lobsters, a peak being reached in the latter year. This is followed in subsequent years by peak percentages for each successive larger length-group, in 1935 the 11″ group, and in 1936 the 12″ and 13″ groups. Thereafter the 8″ and 9″ groups increased greatly.

Statistics in respect of the Fishery District of Eyemouth, as extracted from the relevant annual *Sea Fisheries Statistical Tables* of the Fishery Board for Scotland, for the years 1928 to 1939 inclusive, are given in Table II.

Table II. Fishery Board Statistics, Eyemouth District.

	Number of Lobsters landed (in thousands)	Number of Creels (in thousands)	Number of Lobsters per Creel/year
1928	24·3	4·3	5·7
1929	34·0	4·3	7·9
1930	36·3	4·1	8·9
1931	18·9	3·0	6·3
1932	39·4	2·9	13·6
1933	40·0	2·9	13·8
1934	46·1	3·0	15·4
1935	38·9	3·2	12·2
1936	57·5	3·3	17·4
1937	46·7	3·4	13·7
1938	50·1	3·3	15·2
1939	48·0	3·5	13·7

The general level of fishing for the years 1928 to 1930 inclusive is around 4,100 creels. The average annual catch of lobsters per creel for these years was 6, 8 and 9 respectively. The average catch per creel for 1931 was about 6, namely of the same order, although, in this year the number of creels fell to about 3,000 or less and remained so until 1934. In 1932 and subsequent years the catch per creel rose considerably and was maintained at about 15, at which level it is about double that of the more intensive fishing prior to 1931. In 1935 the number of creels started to rise and this trend persisted until 1939 in which year the number of creels was about 3,500.

The fall, from about 4,100 in 1930 to about 3,000 in 1931, in the number of creels recorded for the Eyemouth Fishery District, was immediately followed by the very pronounced and persistent increase in the average length of the lobsters from 1932 to 1935 during which period the number of creels remained around 3,000. The accompanying increasing catch per creel points to the conclusion that the stock prior to 1931 had been strained and that the increase in average length was a response to the lessened fishing intensity. An alternative explanation, however, may be the incidence of a good year brood. If the latter explanation should be the true one, recovery of the stock should show up in the first instance as a high percentage of 8″ and subsequently 9″ lobsters (a length of 8″ being the minimum marketable size) simultaneously with the onset of the increased catch per creel. This increase, which should have occurred in 1932, was not observed. The same feature would not apply to the recovery of a stock in response to decreased fishing, where a fairly uniform number of minimum sized lobsters are added to the stock but, due to lessened fishing mortality in all length-groups, the average length of the stock builds up and correspondingly the percentage of minimum sized lobsters falls at once, as in fact it did.

The results for Burnmouth strongly indicate that this observed increase in number and in average length of the stock was due to the decrease in the amount of fishing.

From 1936 to 1939 there was a considerable fall in the average length of lobster accompanied by a gradual rise in the number of creels. At the same time the total landings were no more than maintained at around 50,000 (Table II). The increasing fishing effort was therefore giving a progressively lower return by weight. The increasing fishing would appear to constitute one, if not the main, factor responsible for the decreasing length of the lobsters caught but, since the level, by number, of total landings was maintained above that of the period 1928—35, there must be some additional feature. Probably an increased recruitment occurred in 1936 and this level was maintained during 1937, 1938 and 1939. However, even at the new level of recruitment, the fishing apparently was intense and more than offsets the increase in the brood.

An accurate estimate of the concentration of lobsters by sizes on the fishing grounds, and of the overall annual survival rates, is rendered difficult by the absence for the years 1931 to 1938 of a direct measure of the fishing effort.

At Burnmouth the peak catch in 1939 was in the 8″ length-group. It can be assumed that over the range 9″ to 11″ the fishing efficiency of the creel is approximately equal for all lengths. Using the figure of 15% as about the average increase in length at the moult (Herrick 1895, Needler 1948) the percentage overall annual survival rate will be, very approximately:

$$\frac{\text{Catch per 100 creel-hauls of 10·5″ lobsters} \times 100.}{\text{Catch per 100 creel-hauls of 9″ lobsters.}}$$

This formula gives 25% as the overall annual survival rate at Burnmouth for 1938—39.

The catches per 100 creel-hauls at Burnmouth for the months May to October 1939 are shown in Table III. Males and non-berried females are shown separately.

Table III. Catch per 100 Creel-hauls at Burnmouth, 1939.

	May	June	July	Aug.	Sept.	Oct.
Males	3·2	2·3	5·1	10·4	9·9	4·6
Non-berried Females.	2·7	2·1	3·7	8·9	6·9	3·5
Total...	6·0	4·4	8·8	19·3	16·8	8·1

The results cover the main moulting period and the increase in the stock in the second half may be considered as largely due to recruitment. Whilst considerable allowance must be made for variations in the effectiveness of the creel as a sampling device, the figures do indicate an approximate recruitment of 23%. The figures for males (22%) and non-berried females (24%) are in close agreement.

Assuming the stock to be maintained at about the same level as in the immediately previous years, which is suggested by the annual statistics (Table II), recruitment will balance the fishing of the previous year. The overall annual survival rate at Burnmouth for 1938—39 on this reasoning would be about 23%.

After 1939, throughout the war years, the landings

of lobsters in the Fishery District of Eyemouth rose steadily from about 48,000 in 1939 to about 139,000 in 1946. In 1939 the number of creels was about 3,500 and the number of lobsters per creel about 14. In 1946 the number of creels was about 6,300 and the number of lobsters per creel about 22. Since all available evidence points to an intensive fishing during the period prior to the war, and as landings rose continuously throughout the war (Figure 1), the very large stocks and high yield in 1946 can only be attributed in the first place to an upward fluctuation of the brood. It is therefore not surprising that in 1947 and 1948, when the level of fishing remained at about the 1946 level, the catch per creel fell to 14 and 15 respectively. It seems probably that this decrease will be continued, partly on direct account of the brood decrease which must in due course be expected, and partly because of the heavy fishing, if this is continued, in relation to a decreasing stock.

IV. Rousay.

The island of Rousay, together with several other places, constitutes one of the 20 creeks comprising together the Orkney Fishery District. It contributes about 1/12th by value to the total shell fish landed in Orkney. As in the case of Burnmouth observations on the size and sex of samples of about 2,400 lobsters were taken by a fisherman observer during the years 1931 to 1938 inclusive and in 1939 a measure of the fishing effort was noted in addition. The variations in the length composition of the catch, expressed as a percentage of the total catch of 9″ and over, is given in Figure 4. From 1931 to 1934 there was a rising percentage of smaller lobsters, lengths 9″ and 10″, with a corresponding decrease in the percentages of 11″ and 12″ groups. After 1934 the percentage of 9″ lobsters falls away steadily. The most striking feature

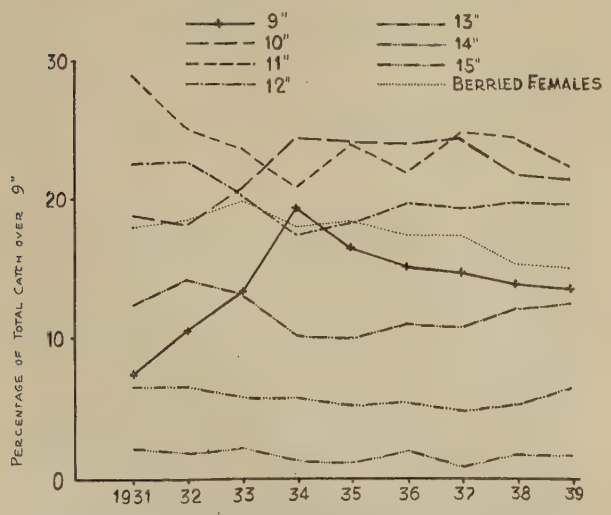

Fig. 4. Annual variation in the percentage length composition of lobsters landed at Rousay in each of the years 1931 to 1939 inclusive.

of observations as a whole is the uniformity of the length composition of the catch which is particularly marked in the years after 1934. There is, however, throughout this later period a persistent though small increase in the average length of the catch, which trend becomes rather more pronounced in 1938—39.

Statistics in respect of the Fishery District of Orkney for the years 1928 to 1939 inclusive are given in Table IV.

Table IV. Fishery Board Statistics, Orkney District.

	Number of Lobsters landed (in thousands)	Number of Creels (in thousands)	Number of Lobsters per Creel/year
1928	122·6	8·7	14·1
1929	123·1	7·9	15·7
1930	139·8	8·3	16·9
1931	145·3	8·9	16·4
1932	138·8	10·3	13·4
1933	164·3	11·6	14·1
1934	126·8	12·3	10·3
1935	127·4	13·8	9·3
1936	130·0	13·3	9·8
1937	113·0	13·4	8·5
1938	119·3	12·8	9·3
1939	88·7	12·4	7·2

The general level of fishing in the years 1928 to 1931 inclusive is based on about 8,700 creels with an average annual catch of about 16 lobsters per creel. In 1932 the number of creels rose and this trend continued steadily until 1937 when the number of creels reached 13,400 near which level it remained for 1938 and 1939. At the same time the number of lobsters per creel fell steadily from about 16 in 1931 to about 7 in 1939.

No records of the number of creels are available for the war years. The total landings of lobsters fell in 1940 to the very low level of about 47,000 (Figure 1). In the period 1941 to 1948 there was an almost continuous and steep increase in the total of lobsters landed in Orkney which in 1948 was about 374,200. The numbers of creels in 1946, 1947 and 1948 were respectively about 14,400, 17,900 and 19,700 and the number of lobsters per creel was around 19. In 1948 therefore there were nearly $2^1/_2$ times the number of creels, three times the number of lobsters landed and higher catches per creel than in the period of uniform fishing from 1928 to 1931.

The catch per creel started to fall as early as 1934 and the average length of lobster in the catch rose from this year onwards to 1939. An increasing average length accompanied by a fall in catch per creel suggests a natural decline in the stock. The landings for Orkney and for the west coast both fell to a minimum in 1940 and thereafter showed a rapid recovery. This fluctuation occurred too soon to be attributable to the effects of the war and contrasts markedly with the trend of landings for 1913 to 1920. There is no record of the number of creels during the first World War, but landings fell away in 1915 and 1916 and the min-

imum was recorded in 1917. Furthermore, had the fall in landings for Orkney in 1938, 1939 and 1940 (Figure 1) been due to the effects of the war, the same factors would be expected to have operated in all areas, but in fact there was no falling off in the landings of lobsters for the Scottish east coast.

All the evidence confirms the conclusion that there was a falling off in the brood which first became reflected in the stock of marketable sized lobsters in about 1935 and reduced the stock to a minimum in 1940, after which the stock recovered, whilst later abnormally good recruitment raised post-war stocks to an exceptionally high level.

V. Comparative Data.

During certain months of 1939 and early 1940, in addition to the observations made at Burnmouth and Rousay, fisherman observers were commissioned at Sandside, Bernera, Staffin and Tobermory (Figure 2). These data afford a comparison of the lobster fishery for 1939 at points around the Scottish coast.

Figure 5 shows the percentage length composition of the catch for all stations. The low average length of lobster in the catch at Burnmouth, in comparison with other areas, is very pronounced. The catch per 100 creel-hauls of marketable lobsters at Burnmouth also is never greater than one third of that of other stations (Table V), whilst the percentage of berried females in the catch is extremely low.

The low catch per 100 creel-hauls at Burnmouth, in comparison with other areas, may be attributable either to the relatively more intensive fishery or to a naturally sparse population. Since there is also a low average size and a low percentage of berried females the conditions cannot be attributable solely to a sparse population.

The catch per 100 creel-hauls at Burnmouth in June, namely before the moulting season, is only about $^1/_4$ that of August by which time the main recruitment to the stock of marketable size lobsters will be completed (see p. 91). In other areas, e. g., Tobermory, the comparable proportion is about $^1/_2$. Furthermore after the peak, subsequent to recruitment, the catch per unit fishing effort falls rapidly

Table V.

Catch per 100 Creel-hauls, average length and percentage of berried females in 1939.

Station	Catch per 100 Creel-hauls	Average length	Percentage berried females
Burnmouth	10·5	8·9	1·8
Rousay	30·6	10·9	13·8
Sandside	34·2	10·6	13·9
Bernera	36·3	10·1	17·1
Staffin	43·4	9·8	14·4
Tobermory	35·1	11·0	18·2

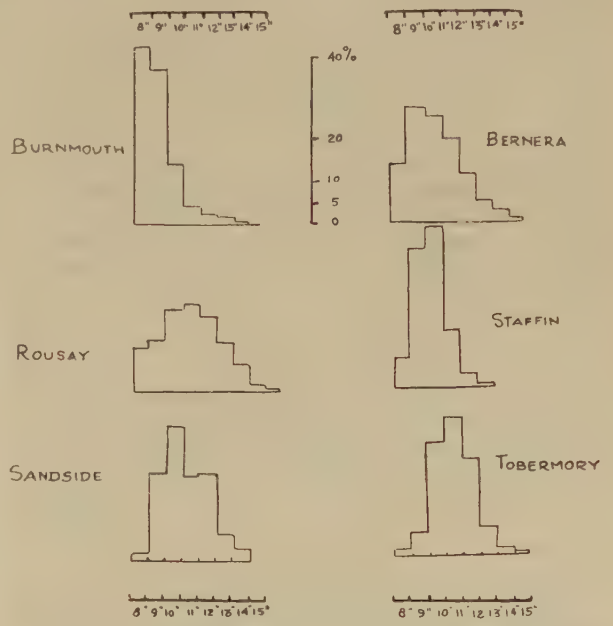

Fig. 5. Percentage length composition of lobsters landed during 1939 at each of six observer stations.

at Burnmouth, due to the intensity of the fishing, whereas in other areas the comparable falling away is very much less pronounced (Table VI).

Whilst for 1939 the total catch of lobsters per 100 creel-hauls is much lower at Burnmouth than elsewhere, the catch of 8″ lobsters is considerably higher

Table VI. **Catch per 100 Creel-hauls of marketable size male and non-berried female Lobsters in 1939/40.**

	Burnmouth		Rousay		Sandside		Bernera		Staffin		Tobermory	
	M.	F.N.B.	M.	F.N.B.	M.	F.N.B.	M.	F.N.B.	M.	F.N.B.	M.	F.N.B.
April	—	—	-					—	—		11·8	11·4
May	3·3	2·7	—	—	—	—	—	—	—	—	13·4	13·3
June	2·3	2·1	13·8	13·5	21·1	10·0	—	—	—	—	16·3	12·0
July	5·1	3·7	11·1	14·2	16·4	8·2	—	—	21·3	14·4	17·5	12·5
August	10·4	8·9	16·4	9·6	15·9	5·5	—	—	28·0	17·5	24·0	23·8
September	9·9	6·9	19·4	10·8	27·3	7·7	—	—	31·8	13·3	—	—
October	4·6	3·5	17·6	8·1	35·3	9·4	29·1	8·1	20·0	6·3	—	—
November	—	—	16·7	8·5	28·3	7·1	22·0	7·4	21·8	13·9	—	—
December	—	—	15·4	8·9	22·2	7·2	25·1	8·0	19·2	9·2	—	—
January	—	—	13·7	8·5	20·0	6·7	19·5	9·4	—	—	—	-
February	—	—	12·5	6·2	29·7	9·0	18·4	8·7				—
March	—	—	13·3	9·0	28·2	8·5	13·6	8·8	—		—	—

than comparable catches (namely peak catches per 100 creel-hauls) in other areas (Table VII). This condition does not suggest a naturally sparse population.

Table VII. Catch of 8″ Lobsters per 100 Creel-hauls in 1939.

	Burnmouth	Rousay	Sandside	Staffin	Tobermory
June.....	1·85	1·65	1·11	—	—
July.....	3·85	0·89	0·91	2·34	1·40
August.....	7·84	1·66	0·22	2·47	4·00
September..	6·67	5·66	—	4·95	—
October....	3·47	4·05	—	4·87	—

All the evidence suggests that the low catch per 100 creel-hauls at Burnmouth, in comparison with other areas, is attributable to the more intensive fishery, at least in part.

The above data indicate also the very pronounced difference between the east coast fishery and that of the west coast, where marketing presents a much greater problem. From the present results it would appear that whilst the east coast is well exploited the west coast could support a more intensive fishery.

VI. Discussion.

Methods of estimating accurately the fundamental statistics, recruitment and growth as well as natural and fishing mortalities, in any lobster population have not been formulated. The recently hatched lobster stages I to III are seldom taken in plankton hauls. After settling in stage IV or V the young lobster virtually disappears until reappearance at a length of 5″ to 6″. These features and the fact that there is no known way of ascertaining the age of lobsters of marketable size, limits the study of a lobster fishery to that of the catch of lobsters of marketable size.

In considering results of commercial lobster fishing, the variations in fishing efficiencies of creels both in relation to different sizes of lobster and between one area and another, as well as differences of practice such as baits in use, all assume importance.

In spite of these limitations the creel still remains the only effective sampling device.

In determining mortality rates the Canadian workers have made extensive use of tagging experiments (Templeman 1935, 1940; Smith 1940, 1941; Wilder 1947). The practice of restricting commercial fishing to a relatively short season, often less than 2 months on anyone ground, makes this a very suitable method. It has however certain objections which are even greater in the case of a fishery such as exists in Scotland, where there is no limitation to the fishing season. A significant and unknown proportion of the tags will be lost through moulting and it is not easy to ensure a uniform distribution of tagged lobsters over the grounds. A measure of the annual mortality rates, both natural and fishing mortalities, by some other means would be a great advantage.

The adult male moults annually, the period of moulting being July and August (Herrick 1895, Templeman 1935). Herrick estimated the growth-rate of the adult lobster in Canada to correspond to about 12·5—15% increase in length. Needler (1948) has quoted the figure 14·3—15·2% as the annual growth. These results refer to the American species. The differences between the American and European species are, however, very few and, although it is desirable to obtain an exact measure of the percentage increase in length at moulting for each area investigated, in the absence of such exact information it is reasonable to take 15% as a provisional figure. Assuming that over the range used the fishing efficiencies of the creels employed are equal for all lengths of lobster, the overall annual survival rate in that range will be given by the following formula.

$$\frac{\text{Catch per 100 creel-hauls in year } T+1 \text{ of male lobsters length } L + \frac{15\,L}{100}}{\text{Catch per 100 creel-hauls in year } T \text{ of male lobsters length } L.}$$

The formula could be modified for use with female lobsters, or for the total males and females by making adjustment for the 2-yearly moulting cycle of adult females, and so provide a check of the above.

The above formula requires a measure of the fishing effort in consecutive years. Such observations are not available in the present data. However, assuming a stock to be in approximate equilibrium the length composition of the stock will remain about the same from year to year. Within these limitations the above formula can be modified to relate to results for a single year. In the absence of any better alternative this method has been employed for the Burnmouth results for 1939.

The adult female lobster, length 10″—11″ and over, moults every other year in alternation with the berried condition. The period during which the female carries the eggs between spawning and hatching is 10—11 months (Herrick 1895). Comparison of the concentration on the grounds of berried females, in a given length-group of 11″ or above, with the concentration of non-berried females of the same length-group in the previous year should give an approximate measure of the overall annual survival rate. This method has the advantage that differences in the fishing efficiencies of a creel for different length-groups is not involved. It is unfortunate that the data available for this paper are incomplete so as to preclude the use of this method.

Deaths due to the hazards of the moulting process will account for a very large proportion of the annual natural mortality. The figure for overall annual mortality obtained by the second method above (using the concentration of berried females on the grounds), does not take account of the mortality at moulting. The method will give a value below the true overall annual mortality and may be more nearly a measure of the annual fishing mortality. The first method, using the percentage growth, should evaluate

the true overall annual mortality rate, but it will be limited in accuracy by the approximation in the value used for percentage growth and by differences, over the reference lengths, in the fishing efficiencies of the creel.

The increase in landings and in catch per unit fishing effort subsequent to the moulting season has frequently been recorded and has generally been attributed to the increased tendency, of the newly cast lobster, to enter the creels on account of hunger. Whilst this factor cannot be neglected, a more likely explanation of the increase is that recruitment, which occurs at this time, has increased the stock. This latter explanation would at least account for the differences between one area and another as instanced on p. 89.

On the above hypothesis, comparisons between one year and another of the catch per 100 creel-hauls of minimum sized lobsters will give relative measures of recruitment. An alternative assessment is obtainable from the total monthly catches of all lengths per 100 creel-hauls. The increase in catch subsequent to the moulting season will be approximately equal to the recruitment.

It is essential to carry out further research and to compare results from tagging experiments with those using the above and other methods.

VII. Summary.

1. The lobster fishery in Scotland, taken as a whole from 1928 to 1948, is divisable into three phases; a period of uniform fishing and yield up to about 1936; a steep decline in landings to a minimum in 1940; finally a period of increasing landings which rise to a level above that of the first period.

2. The above trend is largely due to the west coast and Orkney landings. The east coast is entirely different showing a persistent increase from 1932 onwards. There is no minimum in east coast landings corresponding to that of 1940 which is characteristic of the west and north coasts.

3. The fishery in the Eyemouth Fishery District is substantially similar to that of the east coast area as a whole and is well represented by the fishery at Burnmouth.

4. The length fluctuations, over the years 1931 to 1939, in the stock at Burnmouth, are described and related to the landings of lobsters and the number of creels in the district. The overall annual survival rate at Burnmouth in 1939 is estimated at about 25%.

5. The proportionately high landings of lobsters and the high number of lobsters per creel at Eyemouth in 1946, 1947 and 1948 are ascribed to an upward fluctuation of the brood, although the small landings of 1928—31 appear to have been due to high fishing intensity.

6. The length composition of the stock from 1931 to 1939 at Rousay, a creek in the Fishery District of Orkney, and the landings and the number of lobsters per creel for the District during the years 1928 to 1948 are described.

7. The very considerable decrease in the number of lobsters landed in Orkney during 1939 to 1940 is ascribed to a downward fluctuation of the brood. In 1941 and 1942 there was a recovery in the stock, a trend which further persisted through the war years, apparently resulting in high catches per creel and a high level of landings in the years 1946, 1947 and 1948.

8. Fluctuations in the Orkney fishery cannot be attributed to the effects of the war.

9. Results for Burnmouth and Rousay in respect of 1939 are compared with those for other stations at Sandside, Bernera, Staffin and Tobermory. The average length of lobster at Burnmouth is below that in other areas. The catch per 100 creel-hauls is low and the increase in catch per 100 creel-hauls subsequent to recruitment is high at Burnmouth, in comparison with the remaining five stations. These peculiarities at Burnmouth are mainly attributable to the more intense fishing there relative to the other areas though not necessarily implying overfishing.

10. Two methods for the estimation of annual mortality have been suggested for use in future research.

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20.

Lobster and Oyster in Norway.

By

Alf Dannevig

Lobster.

The lobster is very common along the Norwegian coast to the Trondheimsfjord. It occurs as far north as to the Lofoten islands. The lobster inhabits the shallow waters especially along the coast and in the Skjærgård. In the fjords it occurs more sparsely. It is not fished at a greater depth than about 20 fathoms. The lobster prefers rocky bottom, gravel, and sandy spaces between the rocks. Figure 1 gives the total output of the Norwegian lobster fisheries from 1876—1946. The greatest quantities landed are from the southern and western districts (Figure 2). The Northern district takes in the northern limit of the distribution of the lobster. The fishery has been carried on with the same kind of gear during the whole period, and as it commonly occurs in inshore waters, or near the coast, the development of fishing boats and motors has been of little consequence to the output.

The intensity of fishing is to a very high degree dependent on the economic situation. The fishermen will carry on the fishing during the season as long as it pays. Here the market price is of importance, and also the possibility of having a more profitable occupation. The weather during the season may also be of importance, especially as stormy weather may occasion heavy losses of gear. For the single season the biology of the lobster may also play a major role. In a year with ordinary summer temperatures in the sea water the lobster will usually moult in late summer. In the autumn, the main fishing season, the lobster will thus be in poor condition and eager to take the bait in the pots. If the summer temperature is low, the casting of the shell may occur late in the autumn, and as a lobster before moulting takes only a small amount of food this may have some effect on the output, and relatively few lobsters will have grown to a marketable size. In a year with high summer temperatures the lobster on the southern coast will moult twice. This will augment the stock of commercial lobster. In this way the yearly catches can be influenced by several

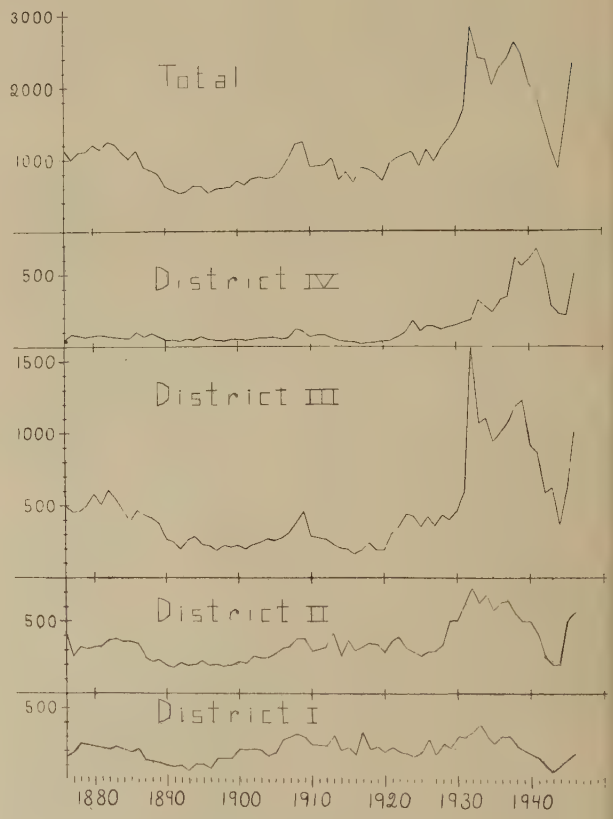

Fig. 1. Total Output of the Norwegian Lobster Fisheries (in thousands) during 1876—1946.

different factors. The main variations in the output, however, are surely caused by variations of the stock. From Figure 1 it is obvious that the variations are fairly parallel in all districts, the northern district,

however, lacks the good period in earlier years. It is of course difficult to state the causes of the variations. The declining values during the war may be ascribed to a lesser intensity of fishing—or the catches being passed direct to the consumer. The good catches after the war may be the result of a greater stock accumulated in the previous years. We know, however, that the lobster in Norway is living near its northern limit, and that the summer temperature of the sea water must be a limiting factor. In Figure 3 we have reproduced the summer sea temperature (May—October) in the Norwegian lobster district from E. Frogner: Means and extremes of sea temperature on the Norwegian coast, Oslo 1948. The temperature is given as a moving mean of 7 years, the time necessary for a lobster to attain a marketable size. It will be seen that high catches correspond to a high summer temperature.

The statistics give no indication of overfishing. This is very interesting as our marking experiments in the southern districts indicate that at least 50 per cent of the marketable lobster is taken every year. There is evidently a good balance between the intensity of fishing and the stock at hand. After each fishing season there will always be left a stock great enough to provide for the future.

In southern Norway we have statistics from about 25 fishermen. The individual catches vary in accordance with the official statistics.

From the same people we also get some information as to the occurrence of undersized lobsters. In the years 1937/1945 more than 70% of the fishermen informed us that lobsters under the size limit (21 cm.) were getting scarce. At Flødevigen (district II) we have carried on experimental fishing since 1928, and the percentage of undersized lobsters in the catches

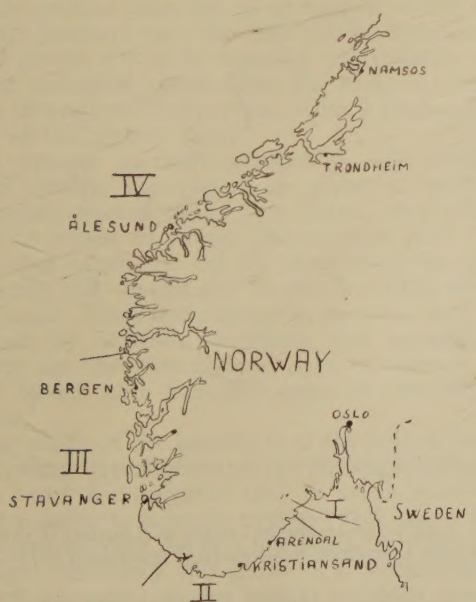

Fig. 2. Chart showing the Districts.

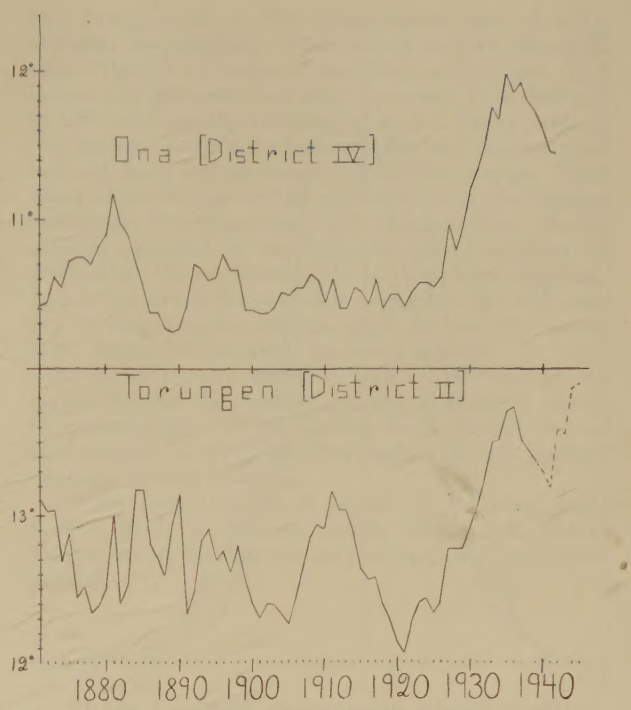

Fig. 3. C° Movable Mean for 7 Years

confirmed the experiences of the fishermen. The scarcity of the small lobsters is somewhat alarming. It may be taken as a warning that the stock of lobster is declining. The problem is, however, complicated. The sea temperature during summer has been relative high during this period, and that means that the lobster will need fewer years to grow into marketable size than in a cold period. The altered relation between undersized and marketable lobster may be explained in that way. Another point of interest is that the natural reduction must be assumed to be proportional to the length of the period of development. Reasonably high temperatures ought therefore to give a better yield of marketable lobster than a cold period. I am therefore not sure that the occurrence of fewer small lobsters may indicate any danger to the stock in future, but surely it is a point of the greatest interest.

Although we have no indication that the stock of lobsters is overfished, this does not mean that the output cannot be raised. By measuring the lobsters—all sizes—caught by the fishermen, it is found that it is the individuals just about the size limit of 21 cm. which dominate (Fig. 4). As the female lobster will not grow fertile till a length of approximately 22 cm. is reached, it is evident that a very high percentage will not have a chance of reproducing themselves. A higher size limit would permit a higher degree of reproduction.

We have marked lobsters between 21 and 22 cm. In 2 years we have recaptured just as many kg. as

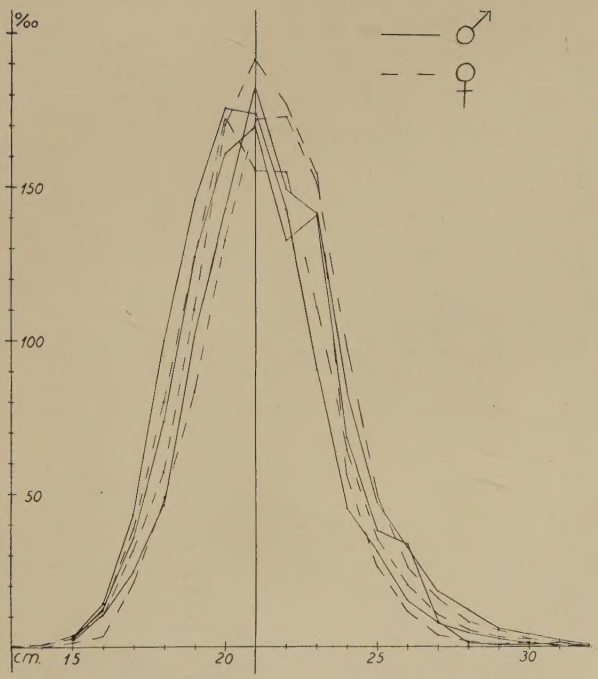

Fig. 4. Lobster Measurements, Districts I and II.

we liberated. We have therefore in Norway brought into consideration the raising of the size limit by 1 cm. At a size of about 21 cm. the lobster has its period of greatest weight increment. When attaining maturity the increment of the females is reduced. It is therefore not sure that a still higher size limit will pay. That problem has, however, not been thoroughly examined.

Figure 5 indicates the yearly increment in length of lobster of different sizes in southern Norway. The increment is computed from marked and recaptured specimens.

It has also been discussed in Norway to prohibit the catch of berried lobsters. This would of course improve the stock to a high degree, but it should mean a very heavy tax on the catches of the fishermen. It has been suggested that the Government during the spring should buy all the berried lobsters from the fishermen and liberate them at the beginning of the closed season. That would probably involve considerable expense to the Government, and the result would be problematic. When the berried lobsters are kept in confinement, the eggs are very often attacked by parasites, and when some lobsters are kept in the same confinement, many eggs are lost. A better method is to take care of the eggs, hatch them and liberate the fry. In Norway we have been experimenting in the raising of the fry to the bottom stage. Apparatus and methods work well, but the experiments to verify the results in nature came to an end at the outbreak of the war. They are now renewed, but as it takes approximately 7 years before the liberated lobsterlings attain a marketable size, we can, as yet, say nothing about the results.

A detailed report on the rearing of lobster larvae is given by Alf Dannevig[1]). In 1933 a new rearing plant was built at Flødevigen on the same principles. We now own 3 old apparatus as described in the paper mentioned, and 20 new ones, each of a dimension of $1{\cdot}28 \times 1{\cdot}45$ and 0·96 m. deep. The output of lobsterlings in the bottom stage has varied between 10,000 and 80,000 a year. The new apparatus has functioned satisfactorily.

The total output depends mainly on: a) the number of larvae available; b) the supply of convenient food; c) the occurrence of parasites; d) cannibalism.

It was found that berried lobsters bought in the market in early summer may have very few eggs left. Most of them have been lost when the lobster has been kept by the fishermen in narrow boxes or during transport. The eggs may also be attacked by parasites. In this way the number of larvae acquired has varied between 200—1200 a lobster. This difficulty has, in recent years, to some degree been overcome by securing the lobsters at an early date and putting them, one in each box, in the hatching apparatus.

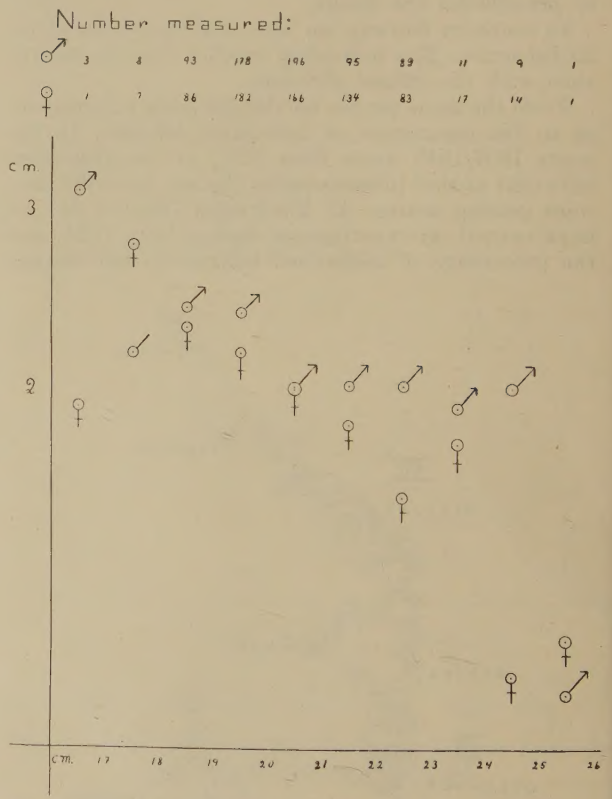

Fig. 5. Yearly Increment in Length of Lobsters in different size-groups computed from marked specimens 1919—1948.

[1]) "The rearing of Lobster Larvae at Flødevigen". Rep. Norw. Fish. and Mar. Invest. Vol. III, No. 9, Bergen 1928.

Here great cleanliness and a good current of fresh sea water is afforded.

The best food for the larvae are the soft parts of the crab (*Cancer pagurus*). Those have, however, been difficult to obtain at reasonable prices. We then turned to fine-grained ox-liver. This is also very suitable. The lobster larvae will be very eager to take it, and it keeps suspended in the sea water. The larvae will grow quickly. This sort of food, however, has in the post-war years been difficult to obtain in sufficient quantities, and therefore we are now feeding with fine grained fresh fish in addition. The results are not so satisfactory when feeding with fish. The cannibalism is greater than when feeding with crabs or liver. The expenses, however, are lower.

The method of cleaning the rearing apparatus by means of fine airbubbles injected into the water-inlet for half an hour in the morning and afternoon, will clean off all food remnants, skins, excrements etc.

In some years, however, the lobster larvae have been attacked by a protozoon, *Ephelota* sp. This protozoon is very common in nature, and the larvae are brought into the hatchery by the water current from the pumps. A moderate attack will not be of any consequence as the protozoon is cast off with the skin at moulting. If the attack is very strong it seems that the process of moulting is inhibited. The larvae will not grow and may succumb. It is difficult to tell what are the reasons for such a heavy attack, but we are inclined to believe that the suction pipe has not been led far enough from the sewage. Thus some of the larvae of the parasites from the rearing boxes may be pumped back into the apparatus. Heavy attacks occurred in the specially warm summer of 1947, when the sea water in the bay was very stagnant. In normal years the attack is negligible. We will now try to lengthen the suction pipe, so that the water inlet comes further away from the sewage.

In normal years the reduction of the number of larvae during the rearing process is brought about by cannibalism. When dealing with lobster larvae this cannot be avoided. The degree of cannibalism depends on the following:

1. The concentration of larvae. 2. Suitable food. 3. The mode of the circulation of the sea water. Eddies where the larvae may accumulate are detrimental.

Oysters.

At the beginning of this century we had in Norway natural oysters at a few localities, especially on the southern coast but also in favourable localities up to the polar circle. At the present time there are but few individuals left. When the stock of old individuals were taken away, the few left were not able to reproduce the stock. The localities where the oyster survived till the present time, are all in narrow waters where the temperature may rise high during summer. The small stocks are to be regarded as remnants of an earlier geological period when the mean air temperature of southern Norway was about 2 degrees higher than at the present time.

At present we have practically only artificially raised oysters. The oysters are grown in baskets of galvanized iron netting, 75×75 cm., suspended in bays by means of buoys. This method is of course somewhat expensive. On the other hand the oysters are under full control and we are free from star fish and snails. There may, however, be some food competition by annelids, ascidians and mussels. The oysters are therefore cleaned once or twice a year. Each basket may hold 250 spats or 100 fullgrown oysters.

The choice of the locality is of the highest importance. Many experiments on the Norwegian Skagerak coast have demonstrated that in many localities it is not possible to raise the oysters at all, they will not grow, and all may die in a few years. In other places the spat ordinarily will grow to a marketable size after 3 summers. In one locality we have observed oysters of a weight of 60—70 g. at 18 months of age. The experiments point to the fact that the variation in the salinity of the sea water is detrimental to the oyster. Therefore, the best localities are found in bays with a narrow and shallow inlet where the salinity below the threshold is very constant. When the depth of water in the entrance is about 1 m., the baskets are placed inside at a depth of about 3 m. below the water surface. In earlier years the oysters were placed 1—2 m. below the surface, and we then had a heavy mortality caused by accumulation of fresh water in the upper layers. This might occur in periods with much rain—or in very cold winters. In earlier years the mortality in cold winters was ascribed to the low temperatures, near zero. But later we have confirmed that during cold winters fresh water may be stored under the ice. In this way it is fresh water and not temperature which has been the detrimental factor. Temperatures about zero are not detrimental to our oyster, and it may sustain temperatures as low as 1·5 C. degrees below zero. During the winter 1941—1942 the temperature in our oyster pond was below zero from January 8th to March 7th, and more than 1 degree below zero between January 28th and February 18th. We had then a stock of oyster in the pond. The mortality was great, but a fair percentage survived.

From our experiments it has also been found that oyster spat brought from the western coast of Norway to our ponds on the Skagerak coast is much more liable to mortality than the oyster reared in our own ponds. This mortality is unlikely to be caused by the transport. The spat will thrive for some time, but the

mortality is so high that the output of adult oysters may be very poor. The oyster spat reared in Western Norway has been acclimatized to more saline water than normally occurs on the Skagerak coast.

In our artificial oyster pond we have tried to raise oyster spat, but the results hitherto have not been satisfactory. In some years we have had great success, in other years the output has been poor. As to the causes for the varying output, we can say very little. Experiments have shown that in some years egg collectors dipped in lime have given a far greater number of spat than collectors without lime. We have till now worked on the hypothesis that the amount of suitable food was the main problem. But although, by means of artificial manure (phosphates and nitrates), we have had a rich plankton, we have not been able to stabilize the output. Through lack of assistance, however, the experiments have not been followed up adequately. We are now inclined to believe that the gas content of the sea water plays a considerable role.

In the laboratory Else Fagerland Dannevig has carried out some experiments on the rearing of oyster larvae in petri dishes. It turned out that success was only attained when using a culture of naked brown flagellates for food.

In order to lengthen the season when oyster larvae are available, some adult oysters are brought into the laboratory in January. The temperature of the circulating sea water is gradually raised to about 20 degrees during February, and in March the oysters will spawn. No food is given except what is contained in the circulating sea water.